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VOLUME XXXIX DECEMBER, 1924 NUMBER 6

Surgery, Gynecology and Obstetrics

WITH

International Abstract of Surgery

Official Journal of the American College of Surgeons

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Published Monthly. Annual Subscription: United States and Canada, $12.00; Foreign, $14.00.
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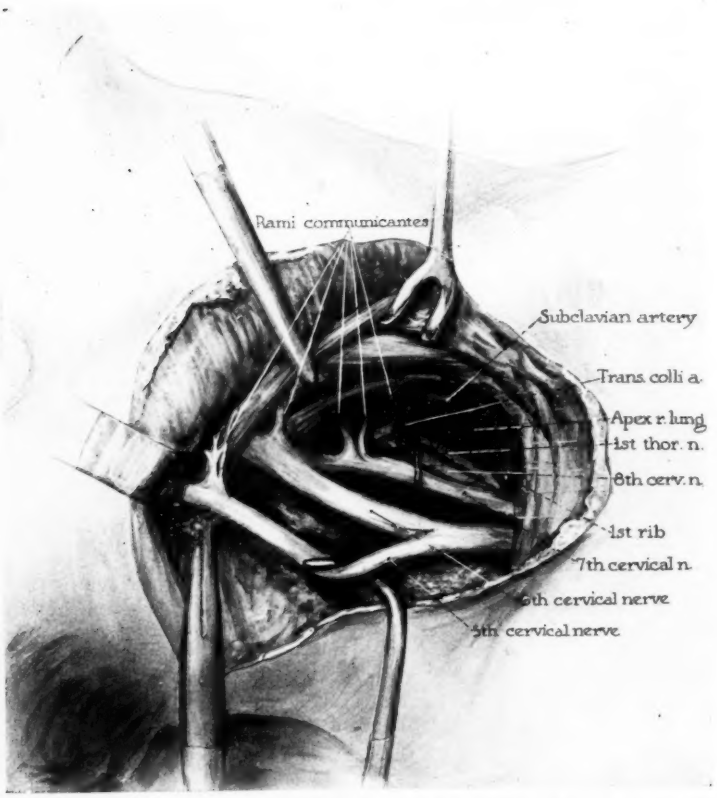

Fig. 8. Dissection completed, showing rami joining nerve trunks as they emerge from intervertebral foramina.

The Treatment of Spastic Paralysis by Sympathetic Ramisection.—Norman D. Royle

SURGERY, GYNECOLOGY AND OBSTETRICS

AN INTERNATIONAL MAGAZINE, PUBLISHED MONTHLY

VOLUME XXXIX DECEMBER, 1924 NUMBER 6

THE TREATMENT OF SPASTIC PARALYSIS BY SYMPATHETIC RAMISECTION

EXPERIMENTAL BASIS AND CLINICAL RESULTS[1]

BY NORMAN D. ROYLE, M.B., CH.M., SYDNEY, AUSTRALIA

Honorary Orthopedic Surgeon to the Lewisham Hospital and to the Children's Welfare Department, New South Wales

PART I.

THE surgical treatment of spastic paralysis has been approached from various points of view. Etiological considerations have determined the procedures which deal with the cerebral cortex itself; abnormal tonic conditions of the musculature have focused attention upon the peripheral nervous system, and the disabilities arising from deformity and contracture have indicated tenotomies and other orthopedic measures.

THE PROBLEM OF TREATMENT IN SPASTIC PARALYSIS

At the outset it may be said that no method of treatment can have much effect in restoring the action of spastic muscles in the absence of definite cerebral control. The problem as it appeared to me was to make effective the existing cerebral control as a preliminary to the educative or re-educative processes. The mere presence of hypertonicity should not prevent the smooth performance of a movement if the muscle groups can be definitely innervated. The clinical picture in spastic paralysis indicates, however, that the effect of cerebral control is nullified by a failure of the normal process or inhibition in the muscle groups antagonistic to those performing a definite movement. To this I have drawn attention in an article in the *Medical Journal of Australia*, February 19, 1919, which includes a record of a clinical experiment on the following plan. An ankle clonus was induced and the dorsiflexing muscles of the ankle joint were then stimulated electrically. The clonus in the plantarflexors was not inhibited during the contraction of the antagonistic muscles unless these muscles were completely contracted. This phenomenon suggested to me that the mechanism of reciprocal innervation was, in some way, not effective in spastic paralysis. It was a feature that could not be explained by the accepted physiology of muscle tonus, and it occurred to me that it might be due to the influence of the sympathetic nerves.

THE DOUBLE INNERVATION OF STRIATED MUSCLE

The presence of non-medullated nerves, apparently of sympathetic origin, supplying voluntary muscle was first demonstrated clearly by Perroncito in 1902, but it was not until 1921 that my attention was drawn to the fact. Other observers verified his findings, and attempts were made to ascertain the function of these non-medullated fibers. DeBoer found that the normal tonus of the hind limbs of the frog and of the cat disappeared after the

[1] The John B. Murphy Oration in Surgery, presented before the Clinical Congress of American College of Surgeons, New York, October 20, 1924

removal of the sympathetic nerve supply. This result has never been accepted; but the idea has been rejected principally because the removal of the sympathetic nerves, in the hands of a number of investigators, has failed to affect consistently the onset or maintenance of decerebrate rigidity.

The principle of reciprocal innervation and many of our ideas on muscle tonus we owe to the work of C. S. Sherrington on decerebrate animals. He found that when the mid-brain was cut through in a certain position, the excitability of the centers controlling the extensor or antigravitational muscles of the head, trunk, and limbs, was so increased that ordinary stimuli arising from the periphery maintained these muscles in a state of reflex tonic contraction. These muscles displayed some remarkable characteristics. If an attempt be made to flex the extended limb of a decerebrate animal, resistance to passive movement will relax after an interval and the limb will tend to remain in the position imposed by the passive movement. The limbs of a decerebrate animal do not always remain extended, but may relax and take up a semiflexed position. If the limb be now passively carried into extension it will remain in the extended position. These phenomena have been described by Sherrington as "lengthening" and "shortening" reactions. The term "plastic" tone was introduced by him to describe this posture maintaining mechanism. J. W. Langelaan recently repeated de Boer's experiments and found that certain changes in tonus followed the removal of the sympathetic nerves in the hind limb of the frog. These changes he ascribed to the loss of the "plastic" element in tonus. He found, however, that the muscles deprived of their sympathetic nerve supply still retained features usually accepted as evidence of tonus and he attributed these features to the presence of "contractile" tone depending upon the medullated nerves. Langelaan did not carry out investigations in decerebrate animals. For this reason his results are still open to question though the test set up is an arbitrary one depending on the assumption that the mechanism of normal tone is responsible for the abnormal conditions seen in decerebrate rigidity.

The undetermined function of the sympathetic nerves supplying voluntary muscles opened up a possibility in solving a clinical problem. I decided to investigate—

1. The function of the sympathetic nerve supply to striated muscle.
2. The possible relationship between the function of the sympathetic nerves and the phenomena of spastic paralysis.

The investigation was actually undertaken with a view to finding some means of relieving the disabilities following gunshot wounds of the cerebral cortex.

Part II. Experiments to Determine the Function of the Sympathetic Nerves

My first plan was to cause spastic paralysis by traumatizing the cerebral cortex in the animal subject and to observe subsequently the effect of the removal of the sympathetic nerves upon the resulting paralysis. I carried out a number of experiments, but these were unsuccessful in that I could not reproduce the spastic condition seen in the human subject following lesions of the cerebral cortex. This plan had to be abandoned, and I was indebted to Dr. J. I. Hunter for the suggestion that the spinal animal would possibly be a suitable medium for observing the effect of removing the sympathetic nerves upon hypertonic muscles.

Experimental Observation upon Spinal Animals

Observations were made upon three spinal animals. The goat was used for these and all subsequent observations because of its well defined abdominal sympathetic trunk. In smaller animals such as the rabbit, it is not always easy to be sure of the complete removal of the sympathetic trunk on one side and on one side only.

In a spinal animal the removal of the left abdominal sympathetic trunk had a striking effect. Following transection of the cord, the lower limbs assumed the position of flexion and adduction. This is more evident when the animal is placed on its back. The removal of the sympathetic nerves on the left side was followed by an immediate change in posture in the left lower limb. This limb assumed a

more extended and abducted position than the right.

The knee and the ankle jerks on the right side were exaggerated and the limb returned to the flexed attitude after the completion of the knee jerk. In the left limb both knee and ankle jerks were obtained, but were of smaller amplitude and were less easily elicited. When the left lower limb was placed in the flexed attitude, the extension caused by the knee jerk was not followed by a return to the flexed attitude but the limb remained extended. The resistance offered to passive movements in the right lower limb was definite, but the left lower limb could be moved passively without any noticeable resistance. The whole reflex activity of the left lower limb was depressed. For instance, passive extension of the right lower limb was followed by two or three movements of flexion, while extension of the left lower limb resulted in only a slight degree of adduction of the thigh. When both lower limbs were extended simultaneously, the right was immediately drawn into the flexed attitude, but the left remained extended. After the sixteenth day, a change appeared in the lower limbs of one animal and the reflex activity on the left side became greater than on the right.

Two of the spinal animals showed these changes, but neither survived 23 days. In the third animal hemisection of the cord on the left side was followed by the removal of the left abdominal sympathetic trunk. Paralysis of both lower limbs followed this procedure but the animal could walk with difficulty at the end of 14 days. The left lower limb could be only defectively controlled at this stage, and would collapse when weight was placed upon it. After an interval of 3 months the animal could walk well and run. This animal was kept for over 12 months, and when placed on its back retained the characteristic change in posture in the left lower limb. In this animal the right limb behaved as in a normal animal and remained extended. The left fell into a position determined by gravity.

EXPERIMENTS IN THE NORMAL ANIMAL

The experimental results in the spinal animal were encouraging, but as I was seeking a therapeutic measure, I had next to determine the effect of removing sympathetic influence from muscles under normal voluntary control. There was also the possibility of wasting to be considered.

The removal of sympathetic nerve supply to the left lower limb of otherwise normal animals did not lead to wasting or apparent loss of power. The animals retained the ability to stand, walk, and run in a normal manner. Certain characteristic differences were observed.

A normal animal, when placed on its back, evidently endeavors to correct a feeling of instability by strongly extending all four limbs. When the sympathetic nerves were removed from the left side, the animal could still extend the left lower limb, but the limb would gradually drop into a more flexed attitude. If the animal were frightened, the limb could again be extended. In these normal animals for some days after the removal of the sympathetic nerve supply, a coarse tremor appeared in the left lower limb, when the animal was resisting a passive movement. In one animal which was closely observed, this tremor disappeared at the end of 11 days. In a typical animal, when both lower limbs were flexed and relaxed, the left one fell away from the flexed position. This occurred gradually in definite jerky movements from position to position until complete extension was reached. There was little appreciable difference in the amplitude of the tendon reflexes on either side. These animals were observed for a period of many months.

EFFECT OF DIVISION OF THE SYMPATHETIC NERVES UPON DECEREBRATE RIGIDITY

The inconsistent results recorded by previous investigators after the removal of the sympathetic nerve in decerebrate animals called for some explanation, and it appeared to me that in some instances the plan of experiment may have been at fault. In addition to those previously reported[1], I have observed the effect of the removal of the sympathetic nerves in a large number of decerebrate animals in which the results have always been consistent. The plan adopted in

[1] Med. J. Australia, 1924, January 26.

these experiments was to remove the abdominal sympathetic trunk in one operation and to allow the animal to recover from the effects of surgical interference before decerebration was carried out. By these two-stage operations any sensory disturbance that might be set up by the wound in the lumbar region is avoided. The decerebration was carried out by gradually removing the brain until the appropriate level was reached. Intratracheal anæsthesia was employed before decerebration and fresh air was pumped into the trachea after decerebration. In several instances I was struck with the difficulty of making accurate observations in the presence of partial asphyxia. The left lower limb was always used in observing the effects of removing the sympathetic nerve supply.

In all these experiments the onset of decerebrate rigidity was characterized by extension of all four limbs, but the left lower limb could be much more easily relaxed than the right. In the intervals, when rigidity of the lower limbs was less it was seen that the characteristics of decerebrate rigidity as described by Sherrington were not present. If the right lower limbs, for example, were passively extended, the limb tended to remain in extension; if the left one were extended the limb would fall into a flexed position as soon as it was released. In other words, lengthening and shortening reactions were very much less evident and in some instances were absent from the left lower limb. Resistance to passive movement was very much greater in the right lower limb than in the left and reflex phenomena were more active on the right side. The knee jerk, for example, was much more easily elicited on the right side. If, however, the left lower limb were put into a similar position to that assumed by the right lower limb, the knee jerk exhibited about the same amplitude of movement, but exhibited a difference in quality. On the left side, extension of the leg imposed by the contraction of the quadriceps muscle was immediately followed by relaxation of the muscle and flexion of the leg. On the right side extension of the leg was maintained in the position imposed by the knee jerk. In some instances, if extension were not completely maintained, the movement of flexion due to the influence of gravity took three or four times as long as the extending movement. These changes in the left lower limb varied with the time interval between the removal of the sympathetic trunk and the operation of decerebration. The longest interval was 73 days, and this gave the greatest contrast in the behavior of the lower limbs.

SUMMARY OF EXPERIMENTAL RESULTS

The complete removal of the sympathetic nerves, from the left lower limb of the normal animal, the spinal animal, and the decerebrate animal produced a similar result in each instance. The normal animal retained the ability to control the movements of the limb, but a characteristic change was observed when the animal was placed on its back. The left lower limb could not then be maintained in steady extension similar to that displayed in the right lower limb. In the spinal animal, the posture of flexion, imposed upon the right lower limb, by the reflex action of the spinal cord, was lost. The left lower limb assumed a posture of extension and abduction under the influence of gravity. In the decerebrate animal the posture of extension was imposed upon the left lower limb as well as upon the right but was not maintained against gravity. In addition, lengthening and shortening reactions were absent on the left side. The "plastic" tone of Sherrington was therefore absent in a limb deprived of its sympathetic nerve supply. All evidence of tone was not abolished by this means. Tendon jerks, for example, could still be obtained and must be ascribed to the presence of "contractile" tone derived through the medullated nerves. The maintenance of posture is thus a function of the sympathetic nerves supplying voluntary muscles. The resistance to passive change in posture in all experimental animals was less after dividing the sympathetic nerve supply of a limb. This was due to the abolition of plastic or posture maintaining tone.

Part III. Experimental Operation on the Human Subject

Spastic paralysis in the human subject has some features in common with the conditions seen in these experimental animals, but in spite

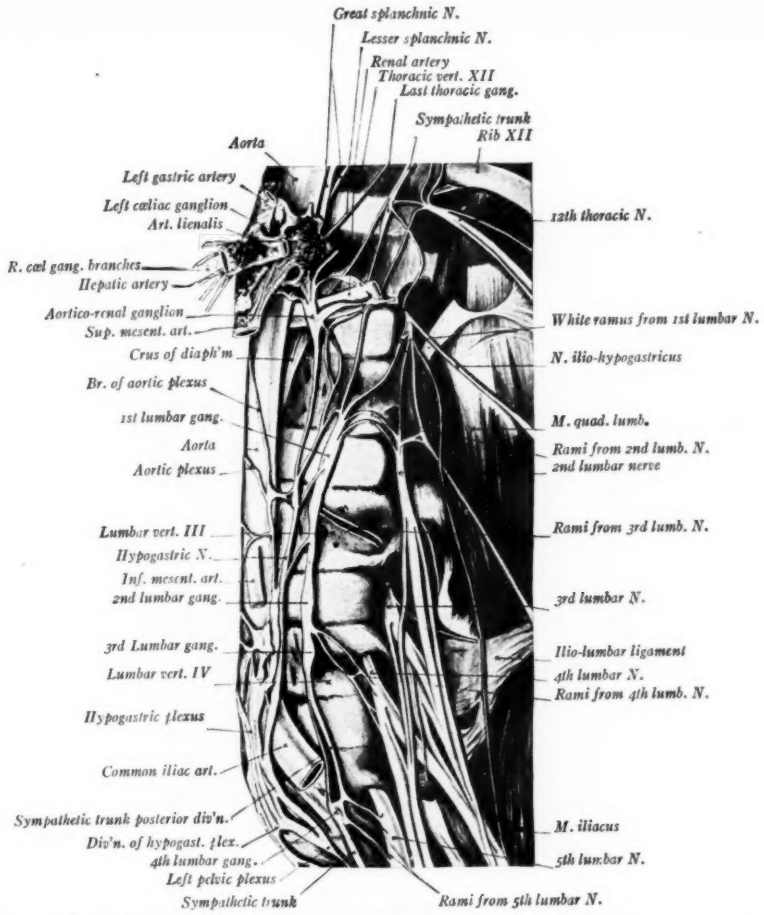

Fig. 1. Dissection of sympathetic trunk and main connections in lumbar region of left side. (Reproduced by courtesy of Dr. T. K. Potts.)

of the results that I had obtained experimentally I could not be certain that the removal of the sympathetic nerves would have a beneficial effect in the human subject. The only possibility of arriving at finality was to perform an experimental operation, and I would like to say in this connection how much I am indebted to my first patient for the manner in which he offered himself, as I was not in a position to assure my patient that a satisfactory result would follow. I could only assure him that all reasonable care would be exercised. The patient considered his disability so great that it could not be made worse, and, I think, this represented a reasonable medical opinion also.

First patient, A. C., had a gunshot wound of the cerebral cortex. The bullet entered his skull just above the left ear and had caused an extensive laceration of the cerebral hemisphere in the region of the central sulcus of the left side. The wound had extended across the middle line on to the opposite cerebral hemisphere. The patient at the time of the operation was 30 years of age and the injury had been received 7 years previously. He had been unable to speak for 3 months and to walk at all for over 2 years after the receipt of the injury. Spastic

hemiplegia affected both limbs on the right side; the left lower limb was spastic also but only in the leg and foot. The knee jerk of the left lower limb was normal, the ankle jerk was exaggerated, and there was an ankle clonus. The whole foot was rigid and the patient's control was very defective. The only deformity present on the left side was a slight degree of talipes equinus. On the right side there was an exaggerated knee jerk, a patellar clonus, an ankle clonus, and an increase in the ankle jerk. The patient could walk, but had the greatest difficulty in controlling the right lower limb. When he placed weight on the limb, there appeared a coarse uncontrollable tremor. He could not stand on the right lower limb, though he could stand comfortably on the left. It was only possible for him to come forward; he could not walk laterally or backward. Talipes equinus was present on the right side. This patient was subject to occasional tonic fits which were of only short duration and which could be easily controlled by the administration of sedatives. The control of his genito-urinary system was normal, but the patient suffered from chronic constipation. This patient was subjected to operation on September 1, 1923.

OPERATION OF THE LUMBAR SYMPATHETIC RAMISECTION

In the animal subject the sympathetic influence was removed from the left lower limb simply by avulsing the left abdominal sympathetic trunk. This operation could not be considered in the human subject on account of the changes that would follow removal of the sympathetic nerves to the abdominal viscera. The sympathetic nerves supplying the muscles of the lower limb arise from the lumbar ganglia and pass through the rami communicantes to the medullated nerves of the lumbosacral plexus. The sympathetic ganglia receive preganglionic fibers from the medullated nerves, and then may be given off as caudally as the third lumbar nerve. Usually the contribution of medullated nerves to the sympathetic system ceases at the level of the second lumbar nerve. The distinction of white and gray rami in this situation is impossible, as it has been shown by Harman that the rami of the second and third nerves may contain both white and gray fibers. The sympathetic supply to the abdominal viscera is given off from the ganglionated trunk in a medial direction and, provided the operation of ramisection were confined to lateral branches directed from the sympathetic trunk to the ordinary medullated nerves of the second, third, and fourth lumbar segments, the effect upon the abdominal organs would be negligible. The division of the sympathetic supply to the fifth lumbar and to the sacral nerves presented a more difficult surgical problem, but this solved itself easily because the sympathetic supply of the viscera is usually given off above the level of the fifth lumbar nerve and complete division of the sympathetic trunk at any point below the level of the fourth lumbar nerve would not affect the viscera. The sympathetic ganglia are not regular structures and do not always correspond in position to the lumbar nerves. The first ganglion usually lies in relationship to the second lumbar vertebra or the intervertebral disc below this vertebra. Below this the trunk may have three or more ganglia. There may, however, be only two definite ganglia.

The plan I adopted in the first operation was to divide the rami communicantes of the second, third, and fourth lumbar nerves and to divide the sympathetic trunk at a level corresponding to the fourth lumbar vertebra. The exact level of section must depend, however, upon the presence of a ganglion in this situation, and also whether that ganglion is supplying any medially directed fibers.

The ganglionated trunk itself is a very variable structure, and this particularly applies to the region of the fourth lumbar vertebra. On many occasions the trunk in this situation has been found to divide, and it was difficult to decide which division continued downward as the main trunk. The plan subsequently adopted was to define the ganglion which gives gray rami to the fourth lumbar nerve, lift it from its bed, and remove its lateral, posterior, and inferior connections. Any medial fibers should be carefully preserved. When this ganglion is not present the ganglion supplying the third lumbar nerve may be unusually large and supply rami to the third and fourth nerves. The size of the ganglionated trunk may vary on each side of the body, and the rami may or may not come from the region of the ganglia.

The size of the rami varies with the number. A single ramus supplying a single nerve may be 2 millimeters in diameter, though the usual

size of a ramus varies between 0.5 millimeter and 1.5 millimeters. The accompanying diagram (Fig. 1) shows that the lumbar ganglion corresponding in position to the second lumbar nerve receives a large white ramus from the first lumbar nerve. In my series of 42 lumbar operations this arrangement was almost invariable; in only one instance was this large branch absent. In the first operation this ramus was mistaken for the white ramus of the second lumbar nerve and was divided, but subsequently the ramus has been avoided unless a special therapeutic effect was sought. In every operation both the white and gray rami of the second lumbar nerve have been divided. The position of the ganglia may cause considerable variation in the position and direction of the rami, but with the exception mentioned above, the rami tend to travel laterally or laterally and downward.

SURGICAL APPROACH TO THE ABDOMINAL SYMPATHETIC TRUNK

The patient should be made to lie on the side opposite to that of operation and should be inclined slightly toward the surgeon who faces the patient's back. The space between the ribs and the crest of ilium should be made as wide as possible by placing a sandbag beneath the patient or better still by using the adjustable support devised for operations on the kidney.

Step 1. The incision is made from the last rib to the crest of the ilium and thence forward to the anterior superior spine of the ilium. If the quadratus lumborum muscle can be palpated, the downwardly directed part of the incision should follow its lateral margin, but if not, the lateral margin of the sacrospinalis should serve as a guide. The forwardly directed part of the incision should lie about 1 centimeter below the actual crest of the ilium. This enables the attachment of the external oblique muscle to be exposed. The flap of skin and fascia outlined by this incision is reflected forward to expose the attachments of the latissimus dorsi to the lumbodorsal fascia and of the external oblique muscle to the crest of the ilium.

Step 2. The trigonum lumbale petiti is next defined and from this point forward the oblique muscles are freed from the crest of the ilium to within 6 or 8 centimeters of the anterosuperior spine of the ilium. In doing this it is possible in most subjects to divide the external oblique through definite tendinous tissue close to its insertion and to avoid cutting the actual muscle fibers. This gives a decided advantage in closing the wound. The internal oblique and the transversus abdominis muscles are divided through the muscle fibers close to their attachment. The dissection is then carried upward and the lumbodorsal fascia is divided at the lateral border of the quadratus lumborum. In doing this it may be necessary to cut through the fibers of the latissimus dorsi.

Step 3. The abdominal wall is now free to be thrown forward and after dividing the fascia transversalis the hand can be passed in front of the quadratus lumborum and the psoas muscles until the medial border of the psoas is palpated. Suitable retractors are then placed in position. Care should be taken not to disturb the fascia covering the quadratus lumborum and the fascia covering the psoas muscle.

In a very fat subject, however, the approach to the sympathetic trunk may be rendered more easy by leaving the fascia transversalis intact except at the medial border of the psoas muscle where it must be pierced to reach the sympathetic trunk. The ganglionated sympathetic trunk can often definitely be palpated where it lies at the medial border of the psoas muscle before it can be seen. The psoas itself sometimes constitutes a difficulty in the adult subject by obscuring the trunk from view, and a suitable retractor is necessary to flatten the muscle. In children and poorly developed subjects this difficulty is not great.

The ganglionated sympathetic trunk will be found lying on the bodies of the lumbar vertebræ near the medial border of the psoas muscle. The abdominal sympathetic trunk on the left side is easy to define, if the medial border of the psoas is sought. In this situation a thin layer of connective tissue passes from the psoas muscles across the sympathetic trunk and great vessels to the region of the psoas on the opposite side. This is easily slit with a

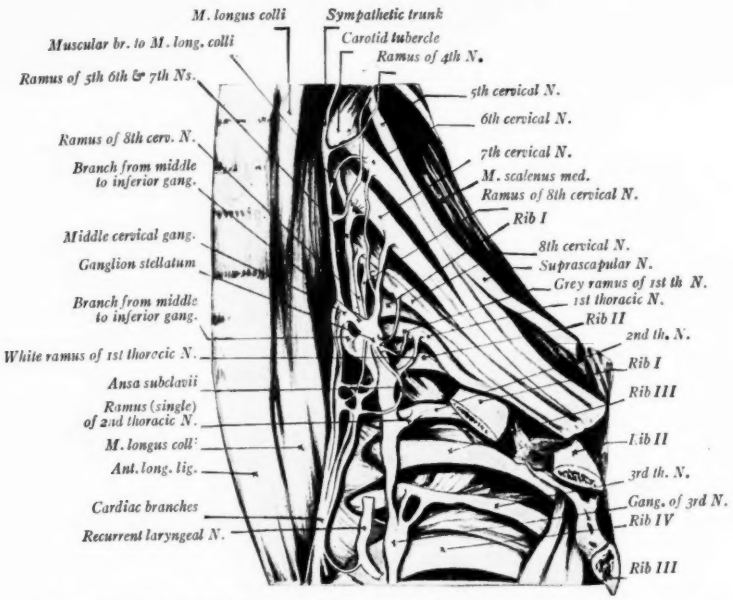

Fig. 2. Dissection of lower cervical and upper thoracic portions of sympathetic nervous system on left side. Muscular scalenus anterior removed. Viewed from in front and to side. (Reproduced by courtesy of Dr. T. K. Potts.)

blunt dissector and the sympathetic trunk comes into view. On the right side the trunk lies under the lateral margin of the inferior vena cava and is usually placed anteriorly to the lumbar vessels. This, however, is by no means constant, for on several occasions, I have experienced difficulty from the lumbar veins crossing anteriorly to the sympathetic trunk. When this occurs the operation may be simplified by removing one or more of these veins. On the left side this complication has not been met, but in young subjects the lumbar arteries can be mistaken for rami communicantes which they sometimes resemble in size and direction. In a few instances the lumbar lymphatic vessels and an unusually low formation of the receptaculum chyli has made the definition of the sympathetic trunk more difficult. In one instance the lymphatic vessels lay between the sympathetic trunk and the attachments of the psoas muscle. On lifting the lymphatic vessels the rami appeared from under their posterior surfaces and patient dissection was required to define each structure.

In defining the sympathetic trunk long blunt dissectors are necessary. My dissectors are 25 centimeters long and have rounded ends. A long probe with a flat handle and curved on its end like a strabismus hook is useful for lifting the sympathetic trunk when defining its branches. Long straight, or slightly curved artery forceps, 20 centimeters long, are also essential and four should be provided. The structures of the abdominal wall and abdominal viscera demand a large, broad, and deep retractor. My own as illustrated for the average adult subject is 8.75 centimeters wide and 12.5 centimeters deep. It is constructed to act as a light, reflecting surface and has a shelf extending forward from its lower edge so as to depress structures medial to the ganglionated cord. The sympathetic trunk and the rami communicantes should be clearly defined before section. The method of dividing the rami communicantes is usually by avulsion. Each ramus may be seized by a pair of artery forceps and drawn away from its lateral connections, though in many instances it is nec-

essary to divide a big ramus with a long pair of blunt pointed scissors. In young subjects the rami may be easily and effectively broken with the blunt dissector. When ramisection of the second, third, and fourth lumbar nerves has been effected, the ganglionated cord is then divided at a level corresponding in position to the fourth lumbar nerve. The operation is then completed. The edges of the lumbodorsal fascia are first sutured in the region of the trigonum lumbale. The oblique muscles are then sutured to the crest of the ilium and a special point is made of suturing the tendinous portion of the external oblique to its original attachment and to the adjacent fascia lata. When this is done carefully the raw area on the crest of the ilium comes in contact with a raw area of considerable width on the under surface of the external oblique tendon and this facilitates adhesion. The lumbodorsal fascia and the latissimus dorsi muscles are then sutured. The skin is closed without drainage.

The whole operation should be performed with very little loss of blood except from small vessels occasionally encountered in freeing the oblique muscles. There is no bleeding in the depth of the wound if the approach is confined to the plane between the peritoneum and the fascia covering the quadratus lumborum and the psoas muscles. Sharp instruments should not be introduced into this wound. The essential dissection can be done with blunt dissectors and long artery forceps.

The iliohypogastric and ilio-inguinal nerves are both retracted forward with the abdominal wall and the ureter with the parietal peritoneum. The incision has been designed as far as possible to divde only fibrous structures in approaching the sympathetic trunk. The internal oblique and the transversus abdominis muscles have, usually, to be divided through their muscle fibers at their insertion to the crest of the ilium. The incision also avoids all important nerves and blood vessels, and, if carefully sutured, should leave the abdominal wall as strong as before the operation.

THE OPERATION OF CERVICAL RAMISECTION

The rami communicantes only are divided in the cervical operation. The sympathetic trunk does not come into the field of operation excepting in the approach to the first thoracic nerve. The rami above the first thoracic nerve are postganglionic fibers, but the first thoracic nerve itself usually has both a white and a gray ramus. The sympathetic rami usually enter the nerve roots of the brachial plexus after they emerge from the intervertebral foramina though occasionally rami will be found joining the nerve roots within the foramina.

Fig. 3. Royle operation. Sympathetic ramisection. Cervical incision. The stages of the operation are shown from this viewpoint.

According to the description of normal anatomy the nerve roots of the brachial plexus should emerge between the scalenus anterior and the scalenus medius muscles. At operation it is exceptional to find this arrangement. It is much more common to find the fifth and sixth roots piercing the scalenus anterior and in several instances these roots have appeared anteriorly to the muscle. The seventh nerve also is commonly separated from the eighth by a bundle of muscle fibers.

The eighth and the first thoracic nerves usually emerge together in a plane posterior to the scalenus anterior. A regular plexus considerably simplifies the operation, while the difficulty is increased if each nerve root emerges separately through the scalenus anterior.

Step 1. The patient lies with the chin turned away from the site of operation and with a small pillow placed beneath the shoulders. The field of operation is reached through an incision extending from the clavicular insertion of the sternomastoid backward and upward across the posterior triangle. In young

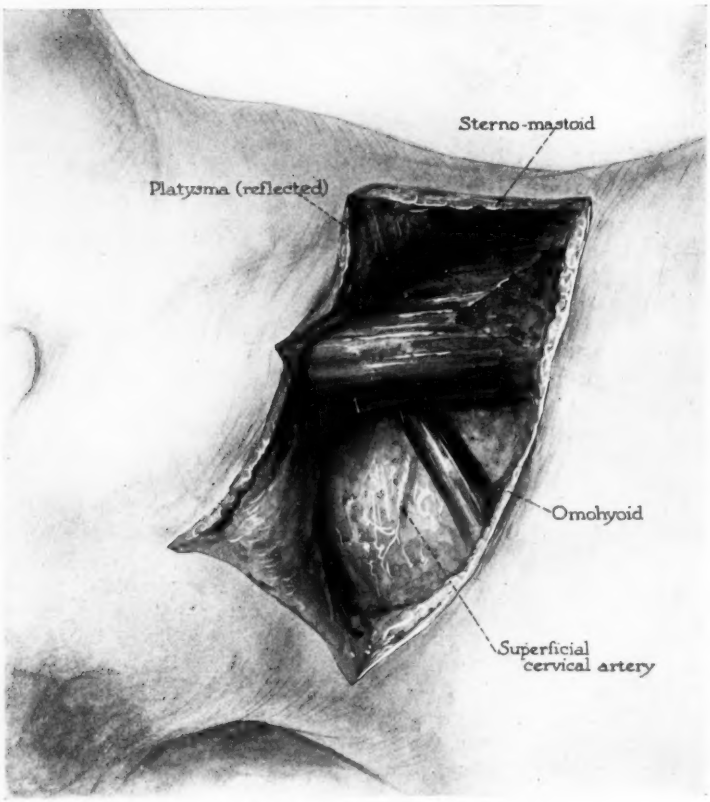

Fig. 4. Platysma reflected.

subjects and in those patients in whom the nerve roots all emerge from behind the scalenus anterior, this incision suffices, but occasionally it is necessary to make a second small incision upward along the posterior border of the sternomastoid to be sure of reaching the connections to the fifth and the sixth nerves. (Fig. 3.)

Step 2. The platysma is divided and the external jugular vein is secured in the line of the original incision. The anterior layer of the cervical fascia is divided and blunt dissection is then carried out to expose the deeper layer of fascia covering the brachial plexus and the scalenus muscles. Between these two layers of fascia the superficial cervical artery will be found occasionally. The transversus colli artery appears in a deeper plane crossing the nerve roots and in my series most frequently between the seventh and eighth nerve roots. To obtain a clearer view of the plexus this artery should be ligated and divided. The omohyoid muscle which also appears in this space, can be easily retracted downward out of the field. (Figs. 4 and 5.)

Step 3. In the upper part of the plexus it is necessary to look for and define the phrenic nerve as it lies on anterior aspect of the scalenus muscle (Fig. 6.). The nerve roots are then exposed and traced to the intervertebral foramina. The subclavian artery is identified and retracted forward to expose the eighth cervical and the first thoracic nerve. The rami communicantes are not easy to define. Those to the fifth and sixth nerves may come across the anterior surface of the scalenus anterior to

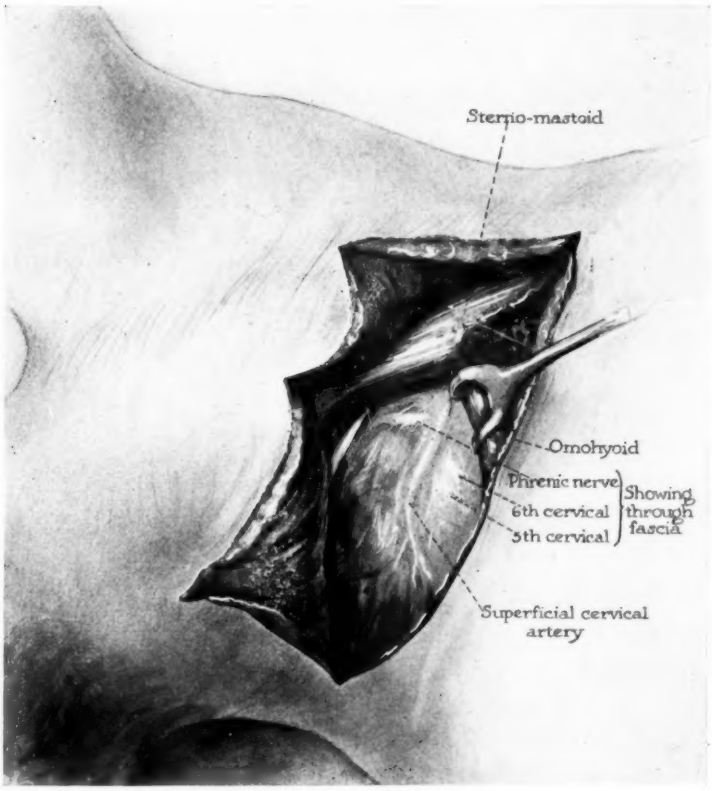

Fig. 5. Omohyoid retracted.

join the nerve trunks or they may come through the muscle itself (Fig. 8). In addition there may be two or more branches and it is necessary in dealing with each of the nerve roots to be sure that all anterior connections are divided right up to the intervertebral foramina. Gray rami may join the nerve roots on their antero-inferior aspects and in many instances must be sought there. This particularly applies to the eighth nerve. Medullated muscular branches will also be found on the anterior aspect of the nerve roots. These may be confused with sympathetic rami and if there is any doubt should be removed. When the phrenic nerve receives communications from the fifth cervical nerve, it will be found necessary to retract it laterally to get a clearer view of the trunk of the fifth nerve. The greatest difficulty will be found in connection with the eighth cervical and the first thoracic nerves. In approaching this part of the dissection the first rib should be palpated and the first thoracic nerve sought as it crosses the neck of the rib. This nerve trunk can then be traced into the thorax. The cervical sympathetic trunk will be found on a plane posterior to the subclavian artery, and if it can be well defined, no difficulty will be experienced in picking up the communicating rami to the eighth nerve. At this point the trunk usually moves to a more medial position as it travels into the neck, but sometimes it will be found lying upon the root of the eighth nerve. The gray ramus of the first thoracic nerve is found on its superior surface medial to the white ramus which should be avoided if possible

Fig. 6. Fascia opened showing scaleni and fifth and sixth nerves joining to form upper trunk.

The rami in this operation may usually be easily broken with a small strabismus hook. After ramisection has been completed, the wound is closed by drawing together the edges of the platysma and by suturing the skin without drainage.

Part IV. Changes Which Occur in the Human Subject After Sympathetic Ramisection

The experimental operation revealed that striking changes in the hypertonic condition of the right spastic lower limb of the first patient followed division of the sympathetic nerves. The changes were typical of those occurring in all cases in which the paralysis was caused by a similar lesion. The first case will be used as an example and comments will be added from subsequent results.

1. *Vasomotor changes.* The patient (A.C.) had very little discomfort following the operation and was examined within 6 hours. The operation had been performed for the relief of paralysis on the right lower limb and this felt warmer than the left lower limb. There was no actual difference of temperature to be detected with an ordinary clinical thermometer. The right lower limb was a deeper pink color than the left and there was capillary dilatation. There was no œdema, but the circumference of the calf was about 1 centimeter larger than that of the left. This flushed appearance was present for some time after this operation but was much more striking in many subsequent patients. On the twelfth day the color was still more pronounced than on the left and returned twice as quickly after pressure. At the end of the seventeenth day

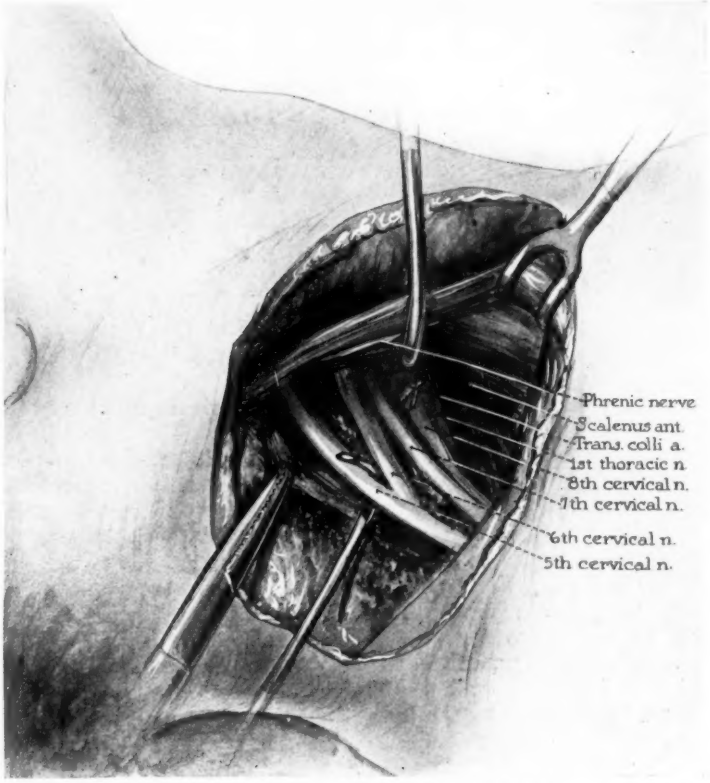

Fig. 7. Scalene muscles separated now showing seventh and eighth cervical and first thoracic nerves.

the vasomotor disturbance had practically disappeared in this patient, and there was very little difference in the rate of return of color after the removal of pressure. The first patient was unconscious of any change in temperature though many subsequent patients described a feeling of warmth. This makes an impression upon them because a spastic limb is usually cold and clammy. One striking change that many patients have reported is freedom from chilblains during cold weather. One small girl wished to have the operation performed on the right upper limb on account of the comfort which followed sympathetic ramisection in both lower limbs previously affected with chilblains.

2. *Changes in tone.* One of the most remarkable early changes was the alteration in tone in the right lower limb in the first patient. This patient was a good subject for an experimental operation since both feet were spastic, and the left one was an excellent control when examining the changes that had occurred in the right. Before operation passive dorsiflexion of the foot was accompanied by ankle clonus and when the foot was released it tended to stay in dorsiflexed position with the tendons of the dorsiflexing muscles standing out prominently. After operation the tendency for clonus to appear on the right side became progressively less and when the dorsiflexed foot was released it fell immediately into plantar flexion. This was a striking contrast to the left foot which still retained a vigorous clonus and remained in the dorsiflexed position for an appreciable time after

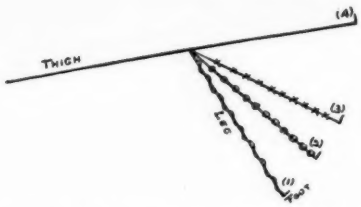

Fig. 9. Diagram of successive knee jerks, showing step ladder effect.

passive dorsiflexion. This was one of the first changes to occur and is still exhibited in this patient, over 1 year since the operation was performed. In these patients reflex activity does not disappear after operation, and it is quite easy, for example, to elicit a knee or ankle jerk. Abnormal reflex excitability is, however, usually depressed after operation. It will be remembered that, in the experiments, reflex activity was exhibited after removal of sympathetic influence, but that the characteristic change in the experimental animals was inability to maintain posture imposed by active or by passive movement.

The normal knee jerk in the human subject can be shown to have a definite phase in which the position of extension imposed by the jerk is momentarily maintained. This is usually credited to a shortening reaction in the quadriceps. In the spastic paralytic the reflex activity may cause much greater amplitude in the knee jerk, and in addition much greater tendency for the position imposed by the knee jerk to be maintained. In one instance, I saw this position maintained for 11 seconds, and in another for some minutes. One particular case illustrated the changes that occurred after ramisection in the shortening reaction of the quadriceps. The patient, W. J., had had a gunshot wound of the cerebral cortex and was suffering from spastic paralysis in the lower limbs and in the left upper limb. The rigidity seen in the lower left limb was so great that when the extended limb was lifted off a horizontal surface the knee remained extended. If the knee were placed in a semiflexed position it would remain semiflexed. When the knee was fully flexed and a knee jerk elicited, a greater degree of extension was imposed and maintained. The effect of a succession of knee jerks may be illustrated as in Figure 9.

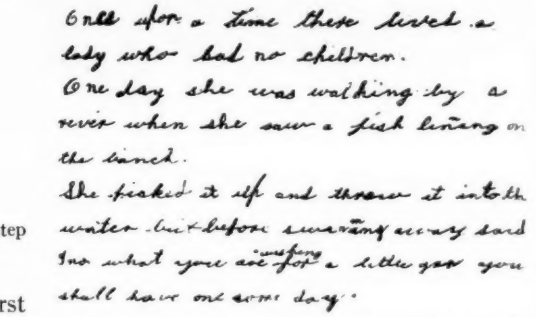

Fig. 10. Handwriting of a child ten years old 9 months after operation. The child could not write legibly before operation.

Extension imposed by the active contraction of the quadriceps was maintained with less loss of position than extension carried out passively. In the latter the leg always fell through an arc of 10 or 15 degrees as soon as support was removed. After operation it was found that the extended knee would remain extended momentarily if lifted suddenly and would then gradually fall. If a knee jerk were elicited in the flexed position, a movement of extension occurred of much greater amplitude than that seen before operation, but the tendency to maintain this position had been lost and the leg fell almost immediately. This loss of rigidity became more evident at longer intervals after operation. There is thus definitely a decrease in the posture maintaining element of tone which depends upon the sympathetic nerves. The element in tone depending upon the medullated nerves and called appropriately contractile tone, also becomes less evident. Contractile tone, however, does not disappear after sympathetic ramisection and, as in the instance quoted, the amplitude of the knee jerk may actually be greater than before operation.

3. Improvements in muscular control. Shortly after the operation the first patient described the feeling of freedom in his right lower leg. On the day following operation the control of the right lower limb had improved. The range of movement of each joint gradually became greater, and the patient learned to control each individual group of muscles.

This continued until the patient began to walk. At the end of 12 days he found he could support himself on the right lower limb and a few days later he was able to walk backward. He had not been able to do this since the day of his injury 7 years previously. On the nineteenth day after operation the patient had so improved as to be able to walk up and down steps using each limb alternatively to negotiate each step. From this onward he continued to improve and learned to relax his former spastic limb while walking.

In regard to voluntary control the outstanding change that occurred in this patient, and in many subsequent patients was that the ability to relax a formerly spastic muscle returned. In the patient, W. J., mentioned above, whose rigid limb was so altered after operation, there was actually no evidence of voluntary control in the left lower limb before operation. Fourteen days later, however, the patient was able to dorsiflex his ankle and to extend his knee, but when the knee was extended he could not voluntarily flex it. He found, however, that he had recovered ability to inhibit a contraction of the quadriceps muscle and the knee would fall into flexion. This was a striking change.

My original observation was the apparent failure of reciprocal innervation and the loss of ability to inhibit the muscles opposing the contracting group. It appears in such a case as this that the posture maintaining action of the sympathetic nerves when abnormal is not influenced by reciprocal innervation. It is possible that normal "plastic" tone is not influenced by reciprocal innervation but is not present in a degree to obstruct voluntary movement. The difficulty of the spastic paralytic is that he cannot freely move from one position to another, although he is able to innervate his muscle groups. It appears, therefore, that this abnormal action of the sympathetic nerves in maintaining postures often constitutes the greater part of the patient's disability.

4. *Improvement in balance.* Disturbance in balance characterizes spastic paralysis in the lower limbs. The first patient could not balance on his right lower limb, but he found he was able to do so 9 days after operation. This experience has been repeated in practically all the operations performed for spastic paralysis in the lower limbs. There is a very simple explanation for the improvement. Before operation the abnormal plastic or posture maintaining element of tone causes the lower limb to be more or less rigid, and the patient cannot change the position of the limb quickly. After operation the diminution of rigidity and the increase in control enables the patient to change position quickly and thus compensate for changes in the center of gravity.

5. *Tremor and fasciculation.* In the first patient a coarse uncontrollable tremor affected the right lower limb before operation when the body weight was imposed upon it, and many other patients have exhibited a similar tremor in spastic lower limbs. There is also present, associated with tremor in spastic paralysis and in a number of other conditions, movements of the muscles which may be described as fasciculation. These movements appear to be an irregular contraction of muscle bundles and waves of contraction may spring up at various points in a muscle quite independently of one another. In many patients limbs affected by tremor and fasciculation also appear to be wasted. In flaccid paralysis wasting is now considered to be due to continued fibrillations or independent contraction of each muscle fiber, and it is possible that in spastic paralysis of certain types, loss of power and wasting is due to continual fasciculation. Certainly results that I have obtained substantiate this view. In the first patient fasciculation was not observed until after the operation, but this appears to have been a clinical oversight, because many other patients have exhibited the condition before operation. In the first patient both tremor and fasciculation gradually disappeared, though a slight degree of tremor remained for some months afterward. In many subsequent patients disappearance of tremor has been a pleasing feature and is probably an evidence of the increasing cortical control. Fasciculations and tremor appear to me to be undoubtedly due to an irregular discharge through the medullated nerves and a disappearance of these manifestations after operation is due to a depression of hyperexcitability in the centers controlling these nerves.

6. Wasting and power. An important question that had to be decided before the sympathetic nerves were cut was whether there would be any wasting following operation. In the experimental animals observations were made which showed that there was practically no variation in the weight between muscles on a normal side and on the side which had been deprived of its sympathetic nerve supply. In one animal which was examined after 73 days, the weight of the tibialis anterior and extensor longus digitorum muscles was actually 5 per cent greater than on the normal side. The muscles of another animal examined at the end of 12 months were about 12 per cent heavier. In the human subject wasting has not been observed to occur after sympathetic ramisection. On the contrary in many instances there has been an actual increase in the size and power of muscles released from sympathetic influence. Some observations have been made by Dr. J. I. Hunter which indicate that voluntary muscle fibers do not each receive medullated and sympathetic nerve supplies, but that there are fibers which receive a sympathetic supply only. He has produced evidence to show that these fibers waste after section of the sympathetic nerves, but that the fibers supplied by ordinary medullated nerves are not affected. If such a thing occurs in a human subject it has no apparent effect upon muscular power and, indeed, we would not expect such a result, since the power of contraction appears to be supplied by fibers activated by medullated nerves.

7. Effect upon the control of the viscera. An unexpected change occurred after sympathetic ramisection, in the first patient. This patient had suffered from chronic constipation and found after the operation that this condition had to a large extent disappeared. I attribute this effect to the removal of the large white ramus coming from the first lumbar nerve to join the sympathetic trunk. Similar effects had been observed in other patients, however, in which this ramus had been left intact, but in my experience the most striking effects occur when this ramus is divided. Other patients have reported an increase in control of the sphincter muscles. In one or two instances frequency of micturition has also been alleviated. In no case has there been any detrimental effect upon the control of the alimentary or urogenital organs, even when ramisection has been carried out on both sides. In every instance great care has been taken to preserve the fibers directed medially from the sympathetic trunk, and the trunk has always been clearly defined before ramisection was attempted. It is conceivable that disaster could follow a carelessly performed operation.

RESULTS OBTAINED BY LUMBAR RAMISECTION IN VARIOUS LESIONS

The operation of lumbar ramisection has been carried out in 42 instances as follows:

a. Following gunshot wounds of the cerebral cortex—7 operations.

b. Vascular lesions of the cortex—5 operations.

c. Spinal injury—4 operations.

d. For spinal lesions such as sclerosis—9 operations.

e. Congenital hemiplegia of infancy—4 operations.

f. Congenital spastic paraplegia—13 operations.

There were no deaths following these operations.

The greatest improvements following lumbar ramisection appeared when the operation was carried out for lesions of the cerebral cortex. This applied not only to gunshot wounds and other traumatic changes, but also to hemiplegia arising from vascular lesions. In traumatic lesions of the spine the result varies apparently with the level of the lesion. For example, a gunshot wound affecting the fifth segment gave a satisfactory increase in control in the right lower limb which was affected. A very good result also followed an operation on a patient with the Brown-Séquard phenomenon, produced by a gunshot wound of the spine at the level of the fifth thoracic segment. On the other hand, spastic paraplegia caused by a fracture of the spine of the lower thoracic region resulted in improvement, but not as great as that seen in traumatic lesions of the upper part of the spinal cord. Lumbar ramisection performed for spastic paralysis following progressive changes in the cord due to diseases such as lateral sclerosis or syringo-

myelia has not yielded encouraging results. The reason for this will be discussed under indications for operation. Results following spastic hemiplegia and paraplegia of infancy certainly justify operative procedures.

In one instance a patient suffering from congenital spastic paraplegia was 16 years of age and had never walked. Both lower limbs were rigid and the degree of voluntary control was minimal. Ramisection was carried out on both sides and 14 days after the second operation had been completed the patient stood and was able to balance for the first time in his life. Three days later he walked unsupported. This remarkable result can be explained from the fact that the child had been swinging himself around on crutches, and his sense of balance was well developed. As soon as the rigidity was diminished in lower limbs he was able to counteract changes in the center of gravity. The range of movement and control of the various movements in his lower limbs steadily improved, and 3 months after operation the boy could walk without any support and with perfect balance.

THE OPERATION OF CERVICAL RAMISECTION

The operation of cervical ramisection was performed for spastic paralysis in the upper limb in 33 instances as follows:

a. Gunshot wound and injury to the cerebral cortex—8 operations.

b. Paralysis following vascular operations —12 operations.

c. Congenital spastic hemiplegia, upper limb—13 operations.

There were no deaths following these operations.

The operation of cervical ramisection was performed also in a number of other conditions which will be referred to in a special report.

The results following cervical ramisectomy were characterized by the same features as results in the lower limb. There was in most instances a great decrease in the rigidity of the limb. An increase in the control of movement was also observed. In certain cases this return of control was very satisfactory and this particularly applies to paralysis following gunshot wounds of the cerebral cortex and in spastic hemiplegia of infancy. The original patient, A. C., had a perfectly useless upper limb. Since this operation was performed 6 months ago, he has gained the power of opening and closing his right hand freely. He is now able to supinate, though not completely, and the movements of the shoulder are continually improving in control and in range. In several instances, the control of intrinsic muscles of the hand improved almost immediately after operation. One very striking result, which has been particularly observed in children, is the ease with which supination is performed after the operation. The specimen of hand writing illustrated in Figure 10 is that of a girl aged 9 suffering with congenital spastic hemiplegia. The writing was done 9 months after operation. Previously her hand writing was illegible. Progressive improvement is reported by every patient of this type.

The least satisfactory results are obtained in paralysis of the upper limb following vascular lesions of the cerebral cortex, and this applies particularly to the fine movements of the hand. Improvement invariably occurs, however, in the control of the movements of the larger groups of muscles. For example, one patient whose upper limb was kept rigidly flexed for 25 years and had not the least sign of active movement learned to abduct the shoulder, to flex the elbow, and to extend the wrist, within 14 days after operation. It is particularly necessary to emphasize, however, that the prognosis as regards recovery in cerebral lesions is not good when the patient has lost all idea of controlling the muscle groups in the hand. Control of movement in the hand is such an intricate mental process and depends so much upon the correct initiation and propagation of nervous impulses that it is difficult to re-establish control.

THE REMOTE EFFECTS OF SYMPATHETIC RAMISECTION

Unexpected effects have been reported by patients in connection with the operation upon the upper limb. In several instances an internal splint associated with general spastic hemiplegia disappeared gradually after operation. The control of the muscles of the face and facial appearance have often definitely improved. For example, several patients had been unable to close the eye on the affected side before operation but have reported the return of this power after operation. Sometimes independent action in closing each eye

was impossible before but was restored after operation. In a number of these patients the eye lid drooped for some time following operation and the pupil became more contracted than on the opposite side. Almost invariably the upper lid resumed a normal posture, though in a few instances the pupil remained smaller in size than on the normal side. The change in the pupil and in the muscles of the eye is probably due to the division of the white ramus from the first thoracic nerve. It is not always easy to distinguish between the white and gray ramus of this nerve and in some cases the white ramus was divided. In certain operations, it is also possible that the cervical sympathetic trunk is subjected to pressure, leaving a temporary depression of function. In several instances, even when ocular symptoms are not present, the face takes on a more relaxed posture, and this adds to the patient's comfort, in that the signs of paralysis are not so evident. The coldness and clamminess of these spastic limbs also disappears, and there is in almost every instance a decrease in the activity of the sweat glands. In the lower limb, on several occasions, patients have reported a tendency for the skin to desquamate. One patient said this occurred about every 6 weeks, but very few patients have noticed this effect. The same patient referred to above thought his nails had become more brittle. He had no discomfort in the limb and was very pleased with freedom from profuse perspiration.

In a number of instances it has been noticed that improvement following ramisection on one side has been followed by improvement on the opposite side before the second operation has been performed. And again, improvement on the first side is augmented when the second operation is performed. This is probably due to the decrease in reflex activity through cutting out one of the reflex arcs. One patient reported relief from stuttering which was present before the onset of spastic paralysis.

Part V. The Influence of Structural Changes Upon the Results of Operation

In paralysis of long standing, adaptive structural changes obstruct early and complete freedom of movement. For example, the presence of pronation deformity retards the acquisition of supination. In some cases this is only a temporary retardation, and the patient is able to overcome the deformity voluntarily. In other instances additional mechanical or operative treatment has to be undertaken to produce the full benefit of ramisection. This is usually confined to correction by plaster of Paris or to simple tenotomy. In younger patients it is advisable to allow return of function to correct deformities as far as possible without further interference. In older patients, where the paralysis has existed for 20 or 30 years, a striking result cannot be expected on account of structural changes, but the result can often be improved by additional operative treatment.

Part VI. The Indications for Operation

Defective cortical control releases the subcortical centers from the effects of cortical inhibition and one expression of their independent activity is the hypertonicity of the muscular system. If the release from cortical control is complete enough and has continued for sufficient length of time muscular rigidity may result. Thus, in the spinal animal the mechanism of the spinal cord causes hypertonicity and a type of rigidity. In the acute condition in the spinal animal the removal of the sympathetic nerves leads to an alteration of the characteristic posture of flexion, but no animal was observed for longer than about 3 weeks. It is not unlikely that observations in a chronic state would reveal that the tendency of the spinal mechanism to impose flexion posture would assert itself. Clinical results of ramisection indicate that uninhibited spinal activity extending over a period of years can impose rigidity which is unaffected by removing plastic tone. The only conditions in which the removal of the sympathetic nerves can have much effect in spinal lesions is when there is enough cortical control to inhibit excessive contractile tone. If, for example, lateral sclerosis has advanced so far that cortical influence upon the spine is minimal, then the spinal mechanism is in control of the situation. The removal of the sympathetic influence may lessen reflex activity, but there cannot be any

substantial gain in the control or the power of movement on account of the nature of the lesion. The position is still more hopeless if muscular wasting and loss of power are present. In lesions which are not progressive, such as traumatic sclerosis, the result of ramisection will depend upon the ability of cortical impulses to pass the pathological block.

CONDITIONS RESEMBLING DECEREBRATE RIGIDITY

Clinical conditions resembling decerebrate rigidity are not amenable to treatment by sympathetic ramisection. One characteristic of the decerebrate animal in the acute condition is the tendency for the limb to assume the posture of extension. It is not unlikely that a chronic decerebrate condition would reveal a much more constant extension than that seen in the acute state. Clinical conditions are seen in which the picture is made up of absence of cerebral control together with hypertonicity of the muscles and constant extensor spasm. These do not yield a satisfactory result. The extensor spasm remains practically unaltered. In these and similar cases, rigidity of extensor type is constant because of the "release of function" in the centers concerned, with the contractile tone of the antigravitational muscles. In the presence of greater cerebral control, the extending tendency may be inhibited and be replaced by a fixed plastic rigidity such as that seen in the spastic paraplegia of infancy. This affects the possibility of treatment, since clinical experience shows that in the absence of any definite tendency for the flexing or extending muscles to undergo reflex contractions and impose positions, the rigidity is due to the sympathetic nerves.

The effects following sympathetic ramisection for spastic paralysis caused by cerebral lesions indicate that the site and severity of the lesion modify the result. When the paralysis is due to trauma of the actual cortex, favorable results may be expected if the remaining cortical control is adequate. Spastic paraplegia and hemiplegia of infancy must be judged according to the mental condition of the patient and by the presence or absence of muscular control. Plastic rigidity may, however, mask the degree of control present and it is not always easy to predict the improvement likely to occur. The prognosis in lesions of the internal capsule and indefinite lesions associated with vascular changes is not good as regards recovery in the upper limb.

THE CLINICAL MANIFESTATIONS OF PLASTIC TONE

The chief indication for operation in spastic paralysis is the presence of excessive plastic tone. This is manifested clinically by the behavior of the muscles in certain clinical tests. For example, under normal circumstances, the knee jerk can be shown to hesitate at the point of maximum excursion, but this hesitation is hardly appreciable to the eye. This hesitation is due to a shortening reaction in the quadriceps muscle, and in spastic paralysis I have observed the shortening reaction to cause the position of extension to be maintained for seconds or longer in an exaggerated knee jerk. This is due to excessive plastic tone and disappears after sympathetic ramisection. Sometimes, as in a complete transverse spinal lesion, the knee jerk is exaggerated and the limb will exhibit a clonus in the extended position, which maintains extension. This is due to excessive contractile tone and may or may not disappear after operation, according to the amount of plastic tone present. Another method of testing is to watch the action of the tendons of the dorsiflexing muscles of the ankle joint, on releasing the foot after passive dorsiflexion. If plastic tone is excessive the tendons stand out prominently and the foot falls slowly into plantar flexion. This test must be used with caution when the habitual attitude of the foot has been plantarflexion. Muscle tone is never so great, even in hypertonic conditions, that all slack disappears in tendons, when the attachments of a muscle are approximated. If the habitual attitude of the ankle has been plantarflexion, the tendons will become prominent only when the dropping foot begins to extend the relaxed tendons. The initial spring into prominence is due to contractile tone and can be seen in both active and passive movements after plastic tone has been removed. The characteristic hesitation of movement will not persist unless the plastic element of tone be increased.

The absence of adequate cortical control of movement is in most cases a contra-indication for operation and this must be clear for two reasons: In the first place, lack of cortical inhibition allows excessive contractile tone to develop through the "release of function" in the lower centers and secondly no improvement in corticospinal connections can be expected to follow the removal of the sympathetic nerves unless excessive plastic tone is the factor nullifying the effect of cerebral control.

Imbecility is an absolute contra-indication and some degrees of feeble mindedness should be similarly considered. It is possible that any factor which restores the control of movement will improve mental deficiency, but the degree of deficiency should be carefully considered before treatment is advised.[1]

Part VII. Postoperative Treatment in Spastic Paralysis

The treatment of spastic paralysis by sympathetic ramisection is sufficient in a few instances to allow the patient to move freely after operation. In the greater number, educative or re-educative measures must be employed. The process of physical education in the normal individual is complete only when there is accurate cortical representation of the movement of each group of muscles. The early reflex movements of the infant have to be analyzed by the growing intelligence until group control is acquired. New purposeful co-ordinated movements are then learned by combining the movements of groups of muscles. When the spastic paralytic is relieved of the obstruction to movement presented by excessive plastic tone, the control of muscle group will very rarely be found to be present. Such movements as flexion or extension of the whole lower extremity are commonly present and for this reason patients will learn to walk, in a manner, long before group control is established. The educative process must be persisted in until group control is established, for it is only in this way that alterations in gait can be made. For example, it is very necessary that flexion of the hip and of the knee be accurately acquired so that the exact amount of flexion of the hip to carry the whole limb forward can be combined with the appropriate amount of flexion of the knee for the foot to clear the ground.

A very important feature of the educative process is to minimize the patient's mental effort. Under ordinary conditions the spastic paralytic has not only to overcome the action of gravity in lifting his limbs but has also to overcome the resistance offered by the uninhibited tone of the muscle groups antagonistic to those performing the movement. This obstruction from tone is very much lessened by operation, but the mental habit of excessive innervation persists. The first point is, therefore, to minimize the mental effort and the second necessity is to eliminate the contraction of any unnecessary muscle groups. This goes a long way toward the establishment of accuracy both in the control of muscle groups and in co-ordinated movements.

The re-educative process is usually more easily accomplished in that cortical representation has been already developed. The pictures of movement become indistinct after years of disability, but a greater difficulty occurs when substitution movements have become established. These are only eradicated by the teaching of group control followed by the practice of correct co-ordinations.

Massage and Electrical Treatment

There is very little to be gained from the use of massage and electrical treatment in spastic paralysis. All forms of irritative electrical treatment are decidedly contra-indicated on account of the tendency to increase the reflex activity of the spinal cord. Education and re-education are psychological processes, and the mere production of muscular contraction by electrical stimulation is really beginning at the wrong end. Massage may have a use in improving the condition of muscles underdeveloped from disuse, but should be employed with caution. The whole object of peripheral treatment is to depress the activity of the nervous mechanism causing hypertonicity, and this will be best accomplished by leaving the muscles unirritated. The lighter forms of massage may sometimes be employed with advantage to bring about muscular relaxation.

[1] See also Med. J. Australia, 1924, September 29.

THE INFLUENCE OF THE SYMPATHETIC NERVOUS SYSTEM IN THE GENESIS OF THE RIGIDITY OF STRIATED MUSCLE IN SPASTIC PARALYSIS[1]

By JOHN I. HUNTER, M.D., Ch.M., Sydney, Australia
Challis Professor of Anatomy, University of Sydney; Honorary Consulting Neurologist, Lewisham Hospital, Sydney

IN a paper read before the Royal Society of London in 1896, Professor C. S. Sherrington (46) called attention to a condition of plasticity of the skeletal musculature of the monkey which supervened upon careful removal of both cerebral hemispheres. He described, for instance, the special characters of the reflex movement of the upper extremity, consisting of a forward step in quadrupedal progression, which occurred following the application of a stimulus, such as heat, to one of the fingers of the hand of an animal in this condition. He recorded that the latent period of this movement was variable but usually prolonged; and that the movement itself was of steady and "smooth" performance. He went on to say, "the most striking feature of the reflex is, however, that when the actual movement has been accomplished the contraction of the muscles employed in it does not cease or become superseded by the action of another group but is continued even for 10 or 20 minutes at a time. The new attitude of the limb is maintained, and that too without clonus or even tremor." Sherrington contrasted this "cataleptoid" effect exhibited by the decerebrate preparation with the short-lasting character of the movements executed as a result of purely spinal reflex action in the spinal animal.

THE PROPERTY OF PLASTIC TONE OF SKELETAL MUSCLE

Sherrington succeeded later in evoking the "cataleptoid" effect simply by placing the limb in the desired posture (49). He employed in these studies a mammalian preparation with mid-brain transected in which all the muscles and nerves of the hind limb, except the vastocrureus and its nerve supply from the femoral nerve, were dissected away. He showed that the decerebrate vastocrureus, along with other antigravity muscles, exhibited two converse reactions. If, starting from the extended position characteristic of the decerebrate posture, the observer forced the knee into flexion the vastocrureus remained fixed after the stretching force had ceased "at a new and increased tonic length." If the knee were now passively extended subsequent to the execution of the movement, the extensor muscle remained fixed "at a new and shortened tonic length." These are respectively the "lengthening" and "shortening" reactions. This property was exhibited not only after forcible flexion of the extended limb, but in the phases of spontaneous relaxation from the extended posture which alternate with the periods of rigidity. Their discoverer called the state of the muscle exhibiting these reactions "plastic tonus."

It is important to notice that Sherrington (loc. cit. p. 144) also showed that the tonus could support approximately the same weight when it kept the muscle in the shortened state (knee extended) as in the lengthened state (knee flexed). The tension of the muscle remained approximately unaltered over a wide range of different lengths of muscle. In other words the degree of plastic tone of the muscle is independent of the length at any given time of the muscle fibers composing the muscle. In this respect Sherrington (49, 50) and others have shown that the reactions of skeletal muscle resemble the properties of smooth muscle, for the latter also "can quite readily adjust itself to different lengths while counteracting one and the same load." Sherrington aptly illustrates this point by reference to the urinary bladder. If skeletal muscle exhibiting the "lengthening" and "shortening" reactions were wrapped round a sac, it would, like the involuntary muscle of the bladder wall, be able to adjust itself to varying capacities without material alteration of the wall tension.

[1]The John B. Murphy Oration in Surgery, presented before the Clinical Congress of American College of Surgeons, New York, October 20, 1922.

Sherrington (49) succeeded in abolishing the "shortening" and "lengthening" reactions of skeletal muscle by severing the posterior nerve roots of the spinal segments connected with the muscle. He proved that plastic tone depended on the existence of a proprioceptive reflex mechanism. In this experiment the autogenous impulses from the muscle were prevented from discharging reflexly through the efferent pathways to endow the property of plastic tone upon the muscle. Sherrington believed that somatic motor nerves formed this efferent connection. The experimental work and human operations of Dr. Royle (44), on the other hand, have shown that the efferent limb of the reflex arc subserving plastic tone consists of the non-medullated postganglionic fibers of the sympathetic nervous system. These reach the skeletal muscles by way of the gray rami communicantes.

SYMPATHETIC INNERVATION OF SKELETAL MUSCLE

In 1879 Tchiriew (52) showed that there were two types of terminal plates in the skeletal muscles of snakes. In addition to the ordinary motor end-plates he found grape-like terminations which were apparently motor in character. Tchiriew demonstrated that transitional forms tended to link these two types together and came to regard the *terminasions en grappes* simply as immature forms of the cerebrospinal motor end-plates. This interpretation did not excite any great interest. Tchiriew noticed, however, a circumstance of great importance in connection with the two types of terminations, namely, that the *terminasions en grappes* were associated with non-medullated nerve fibers, while the motor end-plates were the terminations of medullated nerve fibers. This specific difference between the two sets of nerve fibers led to the inquiry as to whether the two types of end-plates were also specifically different from one another. The answer has been given during the last decade by the application of the experimental method to the elucidation of morphological problems. The following are two reliable experiments. Boeke (8) found in cats that 3 weeks after section of eye-muscle nerves near their origin from the brain stem, many non-medullated fibers had resisted degeneration. He rightly concluded that these were sympathetic fibers from the cervical sympathetic chain which had been transferred to the eye-muscle nerves distal to the point of experimental section of these nerves. Boeke performed the converse experiment of removing the superior cervical ganglion, but beyond the fact that the author was able to record the impression that the non-medullated fibers were fewer in number at the end of 2 weeks, this experiment was unsuccessful. Agduhr (2), on the other hand, after removal of the ganglion stellatum in a cat, was able to find on killing the animal 6 days later, the remains of degenerated non-medullated nerves supplying skeletal muscles of the fore-limb. It must be accepted, therefore, that some, at least, of the non-medullated fibers found supplying skeletal muscle take their origin from the vertebral ganglia of the ganglionated sympathetic chain. To employ the terminology of Langley (31), who confines the term "sympathetic" to the thoracolumbar outflow, the skeletal muscles receive postganglionic non-medullated fibers of the sympathetic nervous system by way of the gray rami communicantes. In addition, of course, this muscle receives the ordinary cerebrospinal nerve fibers of somatic origin. In this sense skeletal muscle has a double innervation.

RELATION OF THE DOUBLE INNERVATION TO THE TONE OF SKELETAL MUSCLE

In 1913, as the result of experiments on frogs, de Boer (13) claimed to have shown that the tonus of the hind limbs disappeared when the rami communicantes of the sympathetic ganglia were severed and deduced that muscle tonus was exclusively governed by the sympathetic nervous system. In 1915 Langelaan (28) differentiated between two elements of tone. He suggested that "one component of the tonus, the plasticity, is controlled by the sympathetic system, and the other component, the contraction, remains under the control of the motor cells of the anterior horn." On repeating de Boer's experiment on frogs Langelaan (29) showed that plastic tonus disappeared after removal of the

sympathetic innervation of the hind limb but contractile tonus remained. He defined plastic tonus as "that state of the muscle in which it has the properties of a plastic body"; and contractile tonus as the property of muscle enabling it to maintain "a state of slight contraction." He used the word "tonus" as the general term comprising both plastic and contractile tonus.

This view has been severely criticized. At the Eleventh International Physiological Congress in 1923, Professors Botazzi and Hess (10) reported that they had been unable to find that interference with the sympathetic system had any effect on the tone or nutrition of skeletal muscle. Adrian (1) in reviewing this question in 1920, came to the conclusion: "There is no doubt that the skeletal muscles are connected to the sympathetic system, but the sympathetic fibers are not concerned with tone."

The strongest argument in favor of this view has been that section of the gray rami communicantes to the nerves of the hind limb failed to prevent the onset of decerebrate rigidity or consistently to diminish the tone of the skeletal muscles of the limb in that condition. After summarizing the experiments of Cobb (11) and others in this connection, Adrian says: "It appears, then, that although removal of the abdominal sympathetic chain is occasionally followed by a diminution of the tone on that side, yet in the majority of these experiments the loss of the sympathetic supply makes no difference; the rigidity is developed and maintained as well on the operated as on the intact side."

Although Langelaan (28) stated in 1915 that it was probable that one of the components in the decerebrate rigidity is a spasm of sympathetic origin, caused by the prevailing of the cerebellum, he did not prove this thesis experimentally.

Dr. Royle's experiments on goats are conclusive on this point. Where decerebration was performed some time, e.g. 73 days after removal of the lumbar portion of the sympathetic chain on one side, deviations from the usual condition of decerebrate rigidity in the hind limb on the side operated upon were observed. These differences occurred both in the phase of extensor rigidity and in the phase of spontaneous relaxation of this condition. This limb is capable of assuming the extended posture but the amount of force required to flex the limb passively is small compared with the force necessary to flex the opposite hind limb. The limb is not rigidly maintained in the extended posture for long periods of time as are the other three limbs. It tends to fall into a position of semiflexion and abduction which is determined by gravity and the inherent equilibrium length of the fibrous tissues composing it. Examination of the limb in this condition reveals the fact that plastic tone is absent, for the "lengthening" and "shortening" reactions are not exhibited (19, 20). This conclusion has been amply confirmed by the results of the operations of sympathetic ramisection obtained by Dr. Royle in patients suffering from spastic paralysis.

The absence of plastic tonus is responsible for the observation that the phase in which the limb on the side operated upon remains extended is short-lasting, for the mechanism is removed which enables the muscle fibers to remain fixed at the length required to maintain this position. No true rigidity therefore develops. Contractile tone, by acting differentially on the extensor muscles, imposes the extended position upon the limb, but in the absence of plastic tone this position is not maintained. Contractile tone, which remains after sympathetic ramisection, is a function of the somatic proprioceptive mechanism.

These two components of tone also confer natural attitudes upon the intact animal. When normal goats, like many other animals, are placed in the supine position, they assume the defensive posture of extension. Dr. Royle (44) found that this position was less consistently maintained by the limb which had been deprived of its sympathetic innervation. This limb tended to fall into a semiflexed and abducted position. Langelaan (29) has shown the effect of sympathetic ramisection upon the hind limb of the frog to be of a similar nature. If compensatory effects from the labyrinth be excluded the limb on the side operated upon fails to maintain itself in the full degree of flexion characteristic of the natural attitude

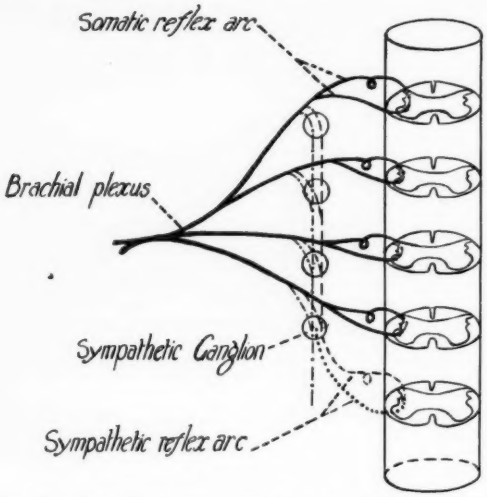

Fig. 1. Schematic representation of the nerve supply of the wing of the domestic fowl to illustrate that the somatic reflex arc and the sympathetic reflex arc are at different levels of the spinal medulla.

of the animal, and returns more nearly to its inherent equilibrium length than the normal limb. I have been able to show (20, 21) that a similar effect occurs in the wing of the fowl upon section of the cervical sympathetic trunk immediately caudal to the roots of the brachial plexus. The folded and adducted position characteristic of the wing at rest is now no longer fully maintained, for plastic tone is absent; but the tendency to assume the flexed position due to contractile tone is still retained. Precisely the same effect as that which follows section of the cervical sympathetic trunk is produced by section of the posterior nerve root of the segment (first thoracic) immediately caudal to the origin of the roots composing the brachial plexus. In this way proprioceptive impulses are removed. These experiments together prove that the plastic tone of the wing is subserved by a proprioceptive reflex mechanism, the afferent and efferent limbs of the reflex arc being at the level of the first thoracic segment (Fig. 1). The somatic reflex arcs subserving contractile tone are situated cranial to this level.

On account of this arrangement the converse experiment may be performed of severing the posterior nerve roots of the segments of origin of the brachial plexus. By this procedure contractile tone is removed and the wing has, therefore, no tendency to take up the usual folded position. On the other hand, due to the presence of plastic tone, the wing will remain in any position in which it is passively placed. It will maintain the normal position if placed in that position (Fig. 2); equally well it remains dependent if it be drawn down to its full extent (Fig. 4), or to any intermediate position (Fig. 3). In other words the flexor muscles exhibit the "shortening reaction" and the "lengthening reaction." If, now, the cervical sympathetic trunk be severed caudal to the roots of origin of the brachial plexus these reactions disappear. This is conclusive proof that plastic tone is subserved by the sympathetic innervation of the skeletal muscles of the wing.

These experiments show that skeletal muscle is under the influence of two proprioceptive reflex arcs—somatic and sympathetic. On account of the limited origin of the sympathetic system the spinal connections of these arcs are situated often at different levels of the spinal cord. For instance, as is shown above, the somatic arc is in the lower cervical and the sympathetic arc in the thoracic region in the case of the wing of some birds (Fig. 1). Together these arcs are responsible for the tone of skeletal muscle. Contractile tone, subserved by the somatic arc, acts on certain muscles only, while their antagonists are reflexly inhibited. This element of tone, therefore, imposes a posture on the part. Plastic tone, a function of the sympathetic arc, maintains this posture once assumed by maintaining the length of fibers of the muscles which exhibit contractile tone. In this sense both arcs are postural in function and tone may be referred to as "postural contraction" (Sherrington, 50, p. 197).

The term "postural tone" should be used to indicate the combination of contractile and plastic tone which are together responsible for the postures imposed by skeletal muscle.

Postural tone is concerned with the active maintenance of a posture against such forces as gravity which tend to impose a passive posture on the part. Sherrington (50, p. 217) has described such active postures as "those

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 2. The wing of a fowl innervated by the sympathetic nervous system only. Contractile tone was removed by severing the posterior nerve roots of the somatic reflex arcs. Plastic tone was still present. The wing was molded passively into its normal position and remained there.

Fig. 3. The same fowl as in Figure 2 with the terminal segment of the wing passively drawn forward. On account of the presence of plastic tone this new position is maintained.

Fig. 4. The same fowl as in the previous two figures, with the wing placed in a dependent position by passive movement. Plastic tone maintains it in this position, contractile tone being absent there is no tendency for the wing to take up the normal folded attitude.

reactions in which the configuration of the body and of its parts is, in spite of forces tending to disturb them, preserved by the activity of contractile tissues, these tissues then functioning statically."

THE RELATIONSHIP OF SYMPATHETIC NERVE TERMINATIONS TO INDIVIDUAL SKELETAL MUSCLE FIBERS

Boeke's extensive researches, as Wilson's review (66) of the subject of double innervation indicates, have been responsible for the general acceptance of the view that the sympathetic nervous system sends non-medullated nerve fibers to skeletal muscles. He believes (6, 7) that each skeletal muscle fiber receives a branch of the sympathetic plexus of non-medullated nerve fibers which are found running between the muscle fibers. Agduhr (2) supports this view. He reports finding the sympathetic termination of a non-medullated fiber on the same muscle fiber as a somatic motor end-plate. The medullated fiber to the latter had degenerated on account of experimental section of the spinal nerve roots having been performed some days previously. If this view is correct then Langelaan's scheme (28) to correlate these facts with the dual structure of muscle fibers is worthy of consideration. Following Boeke he believed that the somatic motor fibers terminated in the anisotropic discs, and that the non-medullated sympathetic fiber terminated in the sarcoplasmic mass in which the striped apparatus is embedded. Botazzi (9) has claimed that the sarcoplasm performs tonic contraction and supports the anisotropic substance in its quicker contraction. According to this conception the sarcoplasm subserves plastic tone and is innervated by the sympathetic ending, and contractile tone is due to a slight degree of contraction of the striped apparatus which is under the control of the motor cell of the anterior column of gray matter of the spinal medulla.

According to this theory sympathetic ramisection consists in depriving the sarcoplasm of each individual muscle fiber of its nerve-supply.

In contradistinction to the findings of Boeke and Agduhr, Perroncito (39) states that in reptiles the same muscle fiber never receives an ending *en plaque*, and an ending *en grappe*. In fact, he argues from this that the grape-like terminations must be motor in character, for each muscle fiber must receive at least one motor ending. This observation is the more interesting because Kulchitsky (27), working on the python, has this year emphasized the point that the medullated and non-medullated nerve fibers never end in the same muscle fiber. Dr. Oliver Latham, of Sydney, work-

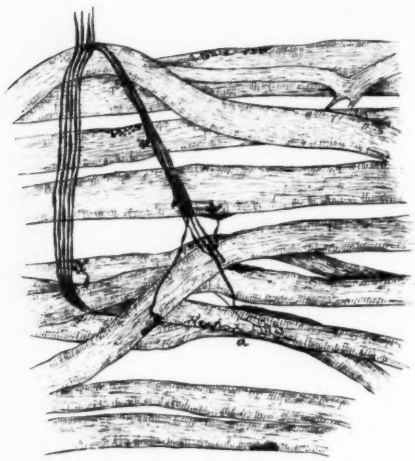

Fig. 5. Gold chloride preparation of the levator palpebræ superioris showing medullated nerve fibers ending in characteristic motor end-plates (somatic) and non-medullated nerve fibers ending in grape-like terminations (sympathetic). Every individual muscle fiber receives one or other of these endings and not both. The muscle fibers shown at *a* are situated on two different planes, the more superficial receives the sympathetic ending and the deeper the somatic ending. (Reproduced by courtesy of Dr. Oliver Latham.)

ing with gold-chloride preparations of the skeletal muscle of the domestic fowl and the goat, has not found an instance of both types of terminations on the same muscle fiber (Fig. 5). Obviously this finding, if confirmed, carries with it an entirely different conception of the neuromuscular mechanism providing the two components of postural tone. It would appear that some muscle fibers which are innervated by somatic motor fibers exhibit, due to reflex activity, a degree of contraction and provide contractile tone. These muscle fibers also actively contract during voluntary movement. Other muscle fibers under the influence of sympathetic endings are lengthened and shortened during the process of active or reflex contraction, and remain fixed at the new length so acquired. They are responsible for the plastic tone of skeletal muscle.

This conception approaches closely the functional duality theory of Gruetzner (16). He believed that in skeletal muscle one set of muscle fibers formed an "intrinsic support" for those fibers which were in active contraction It is especially illuminating in view of the fact that in invertebrates, e.g. bivalve mollusks, two separate muscles are found specialized to perform the functions of movement and fixation respectively. The movement muscle is capable of active contraction. The fixing muscle maintains the posture assumed as a result of the activity of the movement muscle. I believe that the skeletal muscles of vertebrates combine two sets of fibers which are homologous with these separate muscles of invertebrates. The histological and experimental evidence in favor of this view is discussed fully elsewhere (Hunter and Murray, 23).

According to this conception the operation of sympathetic ramisection deprives the fixing muscle fibers of their sympathetic nerve supply. In the absence of innervation these fibers are incapable, after a time at least, of exhibiting the property whereby they may remain fixed at any given length. In consequence the entire muscle is deprived of plastic tone.

THE POSTURAL INFLUENCE OF THE SYMPATHETIC NERVOUS SYSTEM ON SMOOTH MUSCLE

1. Circulatory muscle. The tonus of smooth muscle differs markedly from that of skeletal muscle in that it is manifested apart from the impulses from nerve centers (cf. Bayliss, 4, p. 532). After section of the sympathetic vasoconstrictor nerves a state of moderate contraction still remains which increases during a period of some weeks to become nearly equal to the original condition. Sympathetic ramisection unquestionably leads to a certain degree of vasodilatation and increase in size of the limb, and this procedure may be practised instead of periarterial sympathectomy to remove vasoconstriction. In Dr. Royle's first two patients (44) these vasomotor changes were considerable only in the first week and had practically disappeared as far as palpation could reveal at the end of 2 weeks. Incidentally this fact renders untenable Yas Kuno's explanation (69) that all the changes of tone seen in a limb deprived of its sympathetic innervation are to be accounted for by the increased blood supply, for 12 months

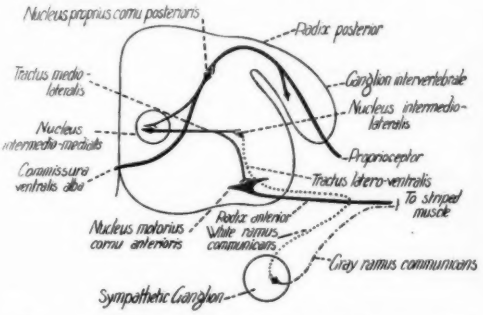

Fig. 6. A scheme representing the spinal connections of proprioceptive fibers from skeletal muscle. (Langelaan and Bok.)

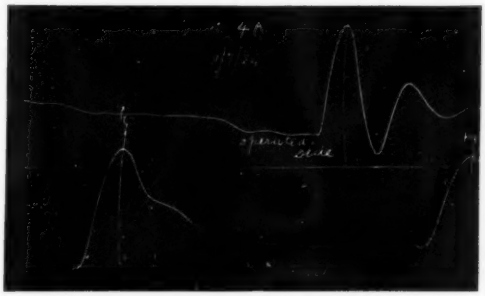

Fig. 7. Graphic record of the knee jerk in the goat. The lower graph shows the normal side, the jerk being elicited with the thigh in full flexion. It shows a prolonged phase of relaxation. The upper graph shows the knee jerk on the other side taken on the same day—three days after sympathetic ramisection. Note the rapidity of the relaxation after the contraction phase. (Reproduced by courtesy of Messrs. F. S. Cotton and R. E. Murray.)

have now passed since the first operation was performed and the change in tone has persisted. Not only does recovery in the tone of circulatory muscle occur after sympathetic denervation but freshly excised arteries have been shown to be capable of exhibiting different diameters under the same wall tension (cf. Sherrington, 50, p. 224). Though this is the case it is probable that living arteries with their sympathetic nerve supply intact exhibit this property to a greater extent. Krogh (26) has demonstrated that the regulation of the caliber of capillaries is very imperfect when their contractile cells of Rouget have been deprived of their sympathetic nerve supply. States of strong contraction alternate with complete relaxation. In this instance therefore the function of the sympathetic nerve supply of circulatory muscle is postural. The neuromuscular mechanism concerned in the regulation of caliber is comparable to that responsible for the maintenance of the plastic tone of skeletal muscle.

2. *Visceral muscle.* Sherrington (50) has applied the term posture to the property of smooth muscle of the hollow viscera which enables these organs to act as a reservoir for contents of increasing volume without the occurrence of a proportionate increase in wall tension. This property is retained to some extent by the excised organ but it is not nearly so adequate as when the nerve supply is intact. The sympathetic innervation of the muscle is responsible for this postural function (18, 19). When released from control, as in cases of spastic paralysis, the sympathetic nerve supply of the smooth muscle of a hollow viscus enables the muscle to assume postures to accommodate increasing contents under the same wall tension to a greater degree than is normally the case. The adequate stimulus for emptying which is effected by the parasympathetic nerves is therefore not attained within the usual limits, and in the case of the bowel constipation results. Experimentally it may be shown (18, 19) that removal of the sympathetic nerve supply to the bowel under these conditions enables the parasympathetic nerves to function when the contents are considerably less than under the abnormal conditions previously existing. The effect of this procedure on the bladder may be to cause frequency of micturition but this is transitory. On this account, as the result obtained in Dr. Royle's first patient indicates, it is justifiable to remove, on one side only, the sympathetic nerve supply (hypogastric nerves) of the sigmoid colon and rectum. The effect on the bowel may be produced by severing the white ramus from the first lumbar nerve to the uppermost lumbar ganglion; or by removing the hypogastric nerves themselves as they pass medially from the lumbar sympathetic trunk; or by severing the trunk proximal to the origin of some of the hypogastric nerves instead of below the fourth lumbar ganglion which is the usual procedure (22, 45). It is evident on the other hand that the lumbar operation may be

confined to section of rami communicantes below that of the white ramus of the first lumbar nerve above mentioned, and the sympathetic visceral nerves are consequently left intact. This enables the bilateral operation to be performed in cases of paraplegia without affecting the bladder and bowel. Similarly gray rami communicantes are alone removed in cervical ramisection. In both the lumbar and cervical operation, therefore, only the sympathetic innervation of the skeletal and circulatory muscle of the limb need be removed (22).

THE CONNECTIONS OF THE SYMPATHETIC REFLEX ARC SUBSERVING PLASTIC TONE OF SKELETAL MUSCLE

It has been shown that a sympathetic reflex arc subserves the function of plastic tone of skeletal muscle. Langelaan (29) in collaboration with Bok, has evolved a scheme of the primary spinal reflex arcs to explain the relationship between the proprioceptive pathways and the somatic and sympathetic motor mechanism connected with skeletal muscle. These connections are reproduced here as Figure 6. It will be seen that these observers believe that a group of cells (nucleus intermedio-medialis) receives the proprioceptive impulses from the cells of the posterior column of gray matter. This nucleus is then connected with both the sympathetic efferent group of cells (nucleus intermedio-lateralis) and the somatic motor cells of the anterior column of gray matter. The somatic motor fibers proceed direct to the muscle. The axons of the sympathetic efferent cells pass by way of the white ramus communicans to a sympathetic ganglion; the postganglionic fibers reach the muscle by way of the gray ramus communicans which joins the spinal nerve.

This scheme also depicts commissural fibers from the cells of the posterior column of gray matter which pass through the ventral white commissure. The physiological evidence which follows indicates that such a path may convey impulses subserving the plastic tone of the musculature of the opposite side of the body. I have been able to show, for instance, that bilateral increase of the plastic tone of the wings of birds follows removal of the major part of one cerebral hemisphere. This rigidity is greater on the ipsilateral side. Now removal of the sympathetic nerve supply to the wing on this side, by severing the cervical sympathetic trunk caudal to the brachial plexus, removes the rigidity not only of this wing but that of the opposite side also. Clearly the afferent impulses from the one wing are responsible for the excess of plastic tone of the opposite wing. This effect is strikingly displayed in some of the cases of paraplegia operated upon by Dr. Royle who first called my attention to the possibility of the explanation given here. Lumbar sympathetic ramisection on one side has greatly diminished the rigidity of the lower extremity of the opposite as well as of the same side.

Intersegmental connections also convey proprioceptive impulses which increase the plastic tone of musculature innervated from higher or lower levels of the spinal medulla. Lumbar ramisection may diminish the rigidity of the upper extremity on the same side. The improvement in speech effected in some patients with spastic paralysis who have been subjected to the operation of cervical ramisection is probably also due to the fact that intersegmental connections convey proprioceptive impulses from the limb musculature to the motor nuclei of the brain stem which supply the musculature of the tongue, larynx, and face.

In mammals spinal connections alone are not adequate to maintain the normal degree of plastic tone exhibited by the skeletal musculature. Sherrington's (49) experiments upon the spinal animal are clear evidence of this fact.

The spinal animal does not exhibit the "lengthening" and "shortening" reactions indicative of the presence of plastic tone immediately after spinal transection. In Sherrington's experiments on dogs, the shortest period after the operation in which he found these reactions present was 16 days, and in this case they disappeared to return at the end of a month after the time transection was performed. "In the early days following thoracic spinal transection, the hind limbs hung almost flaccid with both knees equally flexed under the action of gravity" (49. p. 111).

Pike (40) has pointed out that there are two possible explanations of this condition which is usually designated "spinal shock." First, the conductivity of the spinal reflex arc may be maintained by impulses descending from higher levels; or, second, the function of the morphologically old spinal pathways may have shifted to higher levels so that a period of inactivity supervenes upon spinal transection. According to the latter hypothesis it requires some time for the pristine functions of these persisting spinal reflex arcs to be assumed. This view explains the increasing severity of "spinal shock" in the ascending vetebrate series; the smaller degree of "spinal shock" in young animals; and the presence, in the second stage of complete transverse lesions of the cord, of reactions of the caudal segment of the spinal medulla which are not obtainable in the intact animal. The phenomenon of "spinal shock" is due to the isolation from higher levels of activity of morphologically persistent pathways, which are relatively inactive in the intact animal. We have suggested (24), therefore, the term "isolation inactivity" as being more appropriate for this condition.

Sherrington (50, p. 208) has called attention to the existence of the two possibilities mentioned by Pike in reference to the question of the pathways responsible for plastic tone. "Normally, some prespinal center, or probably several centers, is adjuvant either in the sense that the postural reflex besides employing the spinal centers employs the prespinal as well, or in the sense that the spinal centers which the reflex employs are kept up to the mark for that reaction by influence exerted on them by prespinal." The evidence mentioned above is in favor of the possibility that plastic tone is subserved by a prespinal reflex arc and that the primary spinal sympathetic reflex arc is a morphologically persistent pathway not actively functioning of itself in the intact animal.

No matter which is the explanation, "It certainly appears from Sherrington's researches that as we ascend the animal scale the spinal component of muscle tone becomes progressively more subordinate to the prespinal and of less importance" (Walshe, 58, p. 348). In man the sympathetic spinal reflex has little if any value in the maintenance of plastic tone. The reactions of spinal man are clear evidence of this (cf. Walshe, 59; Riddoch, 41).

It is interesting to recall the fact, already noted, that Sherrington contrasted the long-lasting effect of a reflex movement of the decerebrate animal, in which a posture is maintained for long periods of time, with the short-lasting character of the reflexes of the spinal animal.

Obviously, therefore, reflex flexor movements, which are spinal in origin and subserved by somatic connections, may occur in cases of spastic paralysis in the absence of plastic tone. Hyperactive tendon reflexes alone do not constitute an indication for sympathetic ramisection. The essential indication is increase in plastic tone. Unless this element of tone be exaggerated, rigidity is usually not a marked feature of the spastic limb, and sympathetic ramisection is of no avail. But if exaggerated tendon reflexes and increased plastic tone are both present, removal of the latter element may indirectly cause a diminution in reflex activity. The record of Dr. Royle's first patient (44), on whom lumbar ramisection was performed upon the right side, indicates this fact. This patient was suffering from a gunshot wound of the brain, which though mainly situated on the left side, also extended across the mid-line to the opposite cerebral hemisphere. On this account, in addition to the spastic paralysis of the right side, the left leg and foot exhibited this condition. This circumstance afforded an excellent control following the lumbar operation upon the right side. In the course of a few weeks after the operation in the case of this patient, the ankle clonus, formerly present on both sides, disappeared on the right side, although it was still to be elicited on the left. This clinical observation receives significance from Langelaan's conclusion (28, p. 392) that a clonus is composed by a series of twitches superimposed upon a tonic shortening and that the beginning of clonus is always accompanied by such a tonic shortening. He found this tonic shortening to be a tonic tetanus due to the exalted irritability of the proprioceptive reflex arc.

Dr. Royle has found that the diminution in the activity of the tendon reflexes is not always as marked as in this instance, but that it does occur is undeniable. This result is to be ascribed to an indirect effect upon the somatic spinal arcs. When the rigidity is removed by sympathetic ramisection the excitability of the somatic reflex arc is diminished due to the reduction in the impulses passing into the spinal medulla through the afferent limb of the arc. In the case of clonic action, however, absence of plastic tone would militate in addition against the maintenance of the shortened state of the muscle necessary for the exhibition of the series of twitches constituting the clonus.

Another striking contrast in the first patient was to be seen in the behavior of the right and left foot to passive dorsiflexion. Dr. Royle records (loc. cit., p. 82) that if the left foot were passively pushed into dorsiflexion, there was a tendency for this position to be maintained and only slowly was the attitude replaced by plantarflexion. On the right side, however, passive dorsiflexion of the foot was followed by immediate and complete relaxation. Passive movement provides an excellent test for the presence of plastic tone, because it indicates the presence or absence of "lengthening" and "shortening" reactions. In performing passive movement it is noteworthy that Sherrington (49) has called attention to the fact that in decerebrate rigidity the resistance to passive flexion is at first considerable and then suddenly subsides. This has its counterpart in the "clasp-knife" character of spasticity. This phenomenon is due to the fact that resistance to the force in the first instance is offered by both contractile and plastic tone, and the position can be altered only when the contractile tone is overcome.

Riddoch (42) has pointed out that the "shortening reaction" of the knee extensor may be elicited by suddenly raising the spastic limb from the bed so that the leg is free. If the "shortening reaction" is present the leg is, for a time, held in the position of extension against its own weight. If now the leg be passively flexed the "lengthening reaction" will be elicited. *If present, the "lengthening" and "shortening" reactions constitute an indication for the operation of sympathetic ramisection in cases of spastic paralysis.*

Following sympathetic ramisection in man and animals, even inspection frequently reveals a change in the character of the tendon jerks. The knee jerk, for example, is active and ample, but the leg rapidly falls to its original position when the contraction phase of the jerk ceases (18). De Boer (14) has remarked upon this briskness of the knee jerk after the removal of the rami communicantes of the lumbar sympathetic chain. The tendency to maintain the extended position assumed as a result of the jerk is not so great after removal of the sympathetic nerve supply to the extensor muscle of the knee. Normally this tendency leads to the "shortening reaction" which maintains the extended position after cessation of the jerk contraction during the phase of relaxation. The jerk element is subserved by a spinal reflex and is active in the spinal animal and spinal man. Sherrington (50, p. 211) says: "When the reflex excitability of postural contraction in the knee-jerk muscle is low, as it is in the first period after spinal transection, the jerk is brisk, ample, and easily obtained, and its graphic record is of very simple character. The relaxation fall of the curve is full, drops to the zero abscissa freely and is usually followed by some pendular oscillations, subsiding more or less rapidly. The oscillations are partly due to the inertia of the limb, partly to that of the recording apparatus."

In decerebrate rigidity when the reflex excitability of the postural contraction of the knee extensor is high, on the other hand, the curve of the knee jerk does not drop to the abscissa but exhibits the "shortening reaction." Successive taps may lead to step-like extensions of the leg. Now postural contraction, on which the "shortening reaction" depends, is made up of plastic and contractile components, and the extensor muscle, once the jerk contraction ceases, requires somatic and sympathetic connections for its exhibition in order to retain the extended position of the knee. Sympathetic ramisection, therefore, affects the "shortening reaction" only of the tendon jerk, and not the jerk contraction itself. The tendon reflex combines both the

contractile and plastic elements of tone when normally executed. But, as Langelaan (28) has pointed out, it affords information especially about the contractile component of the tonus which is responsible for the jerk contraction. When plastic tonus is enhanced in degree the reflex appears to be slowly performed due to the delay in complete relaxation of the shortened muscle. It is this feature of the tendon reflex and not the degree of activity of the jerk contraction, which is an indication in cases of spastic paralysis that benefit to the patient will follow sympathetic ramisection. After the operation the tendon reflex appears to be brisk, for plastic tone has been removed, and the relaxation after the contraction has ceased is rapid and complete (Fig. 7).

Langelaan (loc. cit., p. 327) suggests the use in combination of the terms "slow" or "brisk," and "normal," "diminished," or "exaggerated," to describe the degree of plastic tone exhibited by the muscle, and the degree of activity of the jerk contraction of the muscle respectively. *Slowness in execution of the tendon reflexes is an important indication for the operation of sympathetic ramisection for the relief of spastic paralysis.*

Conversely rapidly executed reflex movements usually constitute a contra-indication for the operation. The greater number of spinal injuries are accompanied by this type of reflex and plastic tone is at a minimum. This is due to the fact that a prespinal reflex is essential in higher forms for the maintenance of this property of muscle, and usually, though not always, as will be proved subsequently, this reflex is rendered inactive when the spinal medulla is injured.

THE PRESPINAL REFLEX ARC SUBSERVING PLASTIC TONE

Plastic tone is enhanced in degree in the decerebrate animal. It may appear as a component of postural contraction immediately the mid-brain is transected, so that, normally, prespinal pathways are employed by the impulses maintaining it. When decerebration is performed, plastic tone is increased in degree due to the release of this prespinal sympathetic reflex arc from higher levels of control. In addition to this, contractile tone is enhanced in value because of the release of a somatic prespinal reflex arc. In acute preparations this increase of contractile tone selects the antigravity muscles and their antagonists are reflexly inhibited. The increase in plastic tone rigidly maintains the extended posture which is endowed by contractile tone upon all four limbs of the quadruped, and maintains the condition of "reflex standing" for long periods of time. When the relaxation from the posture of extension occurs, plastic tone still remains as is proved by the presence of "lengthening" and "shortening" reactions.

The prespinal reflex arcs subserve the two components of tone of the normal skeletal muscle and overactivity of these arcs accounts for the phenomena exhibited by the muscle in decerebrate rigidity. It was shown by Sherrington (47) that sections through the medulla oblongata led to flaccid paralysis of the limbs. More precisely, as Magnus has shown, the limits within which transection of the brain stem produces decerebrate rigidity are as follow: the cranial limit is a plane passing dorsally at the level of the caudal limit of the superior colliculus and ventrally in the region immediately caudal to the mammillary bodies. The decerebrate rigidity persists until the level of entrance of the eighth nerve is passed (cf. Walshe, 57). Obviously, therefore, the nuclei which constitute the cell stations of the prespinal reflexes responsible for decerebrate rigidity lie within these limits.

The work of Thiele (53) which is supported by the recent findings of Bazett and Penfield (5) indicates that the integrity of the lateral vestibular nucleus of Deiters is essential for the development of decerebrate rigidity. It may be concluded that this nucleus takes part in the completion of one of the reflex arcs, the hyperactivity of which is responsible for decerebrate rigidity. The vestibulospinal tract, which lies in the region of the emerging motor root fibers of the spinal medulla mainly on the same side as the nucleus from which it originates, constitutes the descending limb of the reflex arc (cf. Lloyd, 32).

The nucleus of Deiters is a special afferent somatic nucleus, and the reflex arc in which it is incorporated, constitutes, therefore, the

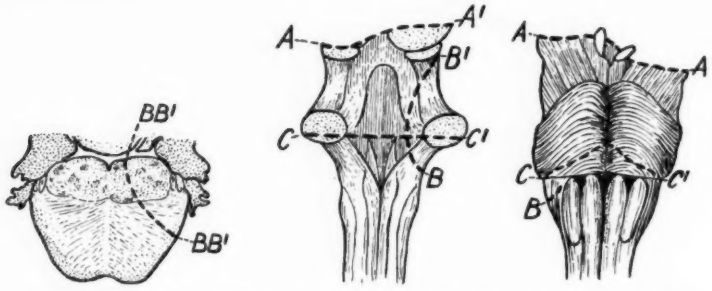

Fig. 8. Diagram to illustrate the various lines of section to produce decerebrate rigidity (A A^1); to remove the nucleus of Deiters (B B^1); and to produce flaccid paralysis (C C^1).

somatic prespinal reflex pathway. It subserves contractile tone which has a selective incidence upon antigravity muscles maintaining the body erect.

The question arises as to whether the nerve cells incorporated in the sympathetic prespinal reflex arc can also be identified. The levels between which section of the brain stem produces decerebrate rigidity suggest that the formatio reticularis of the pons supplies the cell station of this arc. The reticulospinal tracts of the pons are anatomically of special importance. Collier and Buzzard (12) have termed them the pontospinal tracts. The anterior pontospinal tract, which is uncrossed, descends in the lateral zone of the medulla oblongata and the anterior funiculus of the spinal medulla. The lateral pontospinal tract crosses to the opposite side and lies in the lateral zone of the medulla oblongata and in the lateral funiculus of the spinal medulla.

Sherrington's (47) experimental results are compatible with the view that the vestibulospinal and pontospinal tracts convey impulses to the spinal medulla which are responsible for decerebrate rigidity. Section of the lateral half of the bulb abolishes the rigidity on the same side as the lesion. Section of one ventrolateral column of the spinal medulla in the cervical region destroys the rigidity in fore and hind limbs of the same side, while section of one lateral column in the upper lumbar region abolishes the rigidity in the hind limb of the same side as the section. The ascending limbs of these arcs are also in the anterolateral funiculus for section of the posterior funiculus does not abolish decerebrate rigidity.

In an experiment to study this point I have found that plastic tone does not disappear after removal of the nucleus of Deiters. First, decerebrate rigidity was produced by transection of the mid-brain between the superior and inferior colliculi (Fig. 8, *A* A^1). Extensor rigidity developed rapidly and well. Now, in a phase of relaxation when plastic tone was well shown in the right hind limb, I isolated the region of the lateral angle of the fourth ventricle on the right side by a crescentic incision (Fig. 8, *B* B^1). Microscopical examination proved that Deiters' nucleus had been removed and the vestibulospinal tract severed by this procedure. But the "lengthening" and "shortening" reactions were still exhibited. A second transection (Fig. 8, *C* C^1) at the junction of the pons and medulla was then performed. The limbs became flaccid immediately. The "lengthening" and "shortening" reactions were no longer to be elicited. Obviously the plastic tone depends upon a reflex arc which attains a level between the mesencephalon cranially and the medulla oblongata caudally. This is compatible with the view that the pontospinal tracts subserve the function of plastic tone.

It is possible for an incomplete lesion of the spinal medulla to affect the pyramidal and concomitant descending tracts, so releasing the primary spinal arc from control, without affecting in any considerable measure the vestibulospinal and pontospinal tracts. Rid-

doch and Buzzard (43) have recently described cases of quadriplegia from high cervical lesions of the spinal medulla in which the distinctive qualities of decerebrate rigidity were reproduced. Riddoch (42) reports that postmortem examination of one of these patients revealed a tumor in the region of the posterior and lateral columns of the fourth and fifth cervical segments of the spinal medulla. The ventral portion of the cord was relatively little affected.

It is to be clearly borne in mind that the extensor posture is a relatively unimportant character in establishing an analogy between the condition of spastic paralysis in man and decerebrate rigidity experimentally produced. The posture assumed is due to the selective incidence of contractile tone upon the skeletal musculature. Riddoch and Buzzard (43) recorded that, in their patients, the position of flexion was sometimes encountered. On these occasions the flexors were more spastic than the extensors. This condition could sometimes be induced by holding the limbs in the flexed position for a short time. Further, McAlpine (36) reported a case in which rigidity was not confined to extensor muscles, and flexor rigidity of the knee joint was sometimes obtained.

Graham Brown (15) has demonstrated beyond all doubt that plastic flexor tone may be exhibited in the limbs of the monkey. These observations are of added significance in the light of Bazett and Penfield's work (5) on chronic decerebrate rigidity. These authors describe two kinds of decerebrate rigidity, extensor and flexor. Their observations prove that the somatic reflex arcs producing contractile tone may selectively act upon either the extensor or flexor muscles. In extensor rigidity the reflex, of which the vestibulospinal tract is the descending limb, is involved. In flexor decerebrate rigidity the primary spinal reflex is, no doubt, responsible for the activity, for severe injury to the spinal medulla produces paraplegia in flexion (cf. Walshe, 59, p. 317). In both types of decerebrate rigidity plastic tone, which is enhanced in degree, and co-exists with contractile tone, is maintained by the sympathetic prespinal reflex arc. In each case it is inhibited in the antagonists of the muscles exhibiting the rigidity.

Inhibition in the antagonists is not so complete in man as it is in the condition of acute decerebrate rigidity in animals. Dr. Royle has called attention to this point. Riddoch (42) makes mention of the fact that though the antagonistic muscles are relatively relaxed "they are certainly in stronger contraction than the corresponding muscles of a healthy individual."

I believe that the explanation of this is that in the acute decerebrate preparation the extensor reflex arcs, chiefly through the nucleus of Deiters, immediately manifest increased activity. The isolated flexor spinal arcs regain activity only after a period of inactivity. When this occurs the selective action of contractile tone on the extensors is not so complete for the spinal arc endows this aspect of tone upon the flexors also. Reflex inhibition is now not complete. Bazett and Penfield's experiences with the chronic decerebrate animal support this view. Moreover, in patients suffering from spastic paralysis, plastic tone is not inhibited in antagonistic muscle groups which accounts, in some measure, for resistance to active, reflex, or passive movement of the limb.

I have commented on the work of Bazett and Penfield to emphasize the fact that the posture of the patient is not the all-important criterion of rigidity. Even the flexed position may be due to a combination of both contractile and plastic tone which together cause rigidity in the sense in which this term is employed in this paper. Conversely, the extensor position may be wholly due to contractile tone. Sympathetic ramisection in such a case would be of no avail. Extensor fits usually fall into this category. This is beautifully illustrated in a case recently reported by Walshe (56), in which two stages of the illness were observed. In the first stage the patient exhibited a condition of decerebrate rigidity. The limbs were extremely plastic and tended to remain for a considerable time in any position passively imposed upon them. The lower extremities were extended and adducted and the feet plantarflexed. As is usual in man the upper extremities were semiflexed at the elbows, with the forearms pronated and the wrists and digits flexed. This attitude

often replaces that of extension of the fore limbs of quadrupeds because the upper extremities are no longer "simple locomotor props" (cf. Walshe, 61). Passive movement revealed the presence of the "clasp-knife" character of the spasticity. The tendon jerks exhibited tonic prolongation, and in some instances in response to repeated taps "step-ladder" shortening of the muscle was observed. In recording these features, Walshe established beyond doubt the identity of this condition with decerebrate rigidity experimentally produced.

In the second phase of the illness this condition was replaced by the progressive failure of reflex activity and deepening coma. In this stage tonic fits appeared as a concomitant of cardiac and respiratory irregularities. In these fits the respiratory muscles were fixed and the limbs became so rigid in their customary posture that no tendon reflexes could be elicited. In severe fits of this kind the head retracted forcibly. At this stage none of the essential qualities of decerebrate rigidity, enumerated as characterizing the first phase of the illness, were exhibited for plastic tone was not apparently enhanced in degree. The second phase was in all probability due to hyperexcitability of the somatic reflex pathways due to asphyxia or anæmia (cf. Walshe, 62 and 63; Stewart and Pike, 51; Warner and Olmsted, 64; Hunter and Royle, 24). The fits are not comparable to decerebrate rigidity in which the enhanced tone is due to release in function of two prespinal reflex arcs—somatic and sympathetic. Yet the posture displayed in each condition is the same. Taking into account the results of tests for the presence of plastic tone in addition to posture Walshe (57) and Riddoch (42) have been able to establish the essential identity of decerebrate rigidity and the condition of spastic paralysis, such as that which occurs in hemiplegia, quadriplegia, and the extended form of spastic paraplegia.

When the sympathetic gray rami distributed to skeletal muscle are stimulated the muscles supplied show no sign of shortening (Bayliss, 4, p. 545). But, of course, this is to be expected if the sympathetic innervation is responsible for plastic tone of skeletal muscle. The result of appropriate stimulation would be to fix the muscle fibers governed by the sympathetic system at their existing length. Obviously, therefore, athetoid movements or intermittent spasms of muscle, which depend upon the process of shortening of muscle fibers, are not dependent upon the sympathetic innervation of the muscle groups affected. No appreciable improvement of these conditions follows sympathetic ramisection, and their presence is, in general, a contraindication to the performance of the operation. If during development with education marked improvement or loss of these features takes place, any remaining rigidity, which may be dependent upon the existence of plastic tone, may then be examined with a view to subjecting the patient to operation to enable further progress in education to proceed.

AFFERENT PATHWAYS MODIFYING THE PRESPINAL REFLEX ARCS SUBSERVING MUSCLE TONE

In the foregoing description the afferent impulses responsible for the maintenance of tone have been described as owing their origin to the muscles themselves. Undoubtedly the proprioceptive reflex arcs alone are capable of maintaining decerebrate rigidity. Other influences, while not essential to this condition, are capable of modifying it. The work of Magnus and de Kleijn (35) has been responsible for the accurate identification of these pathways and for a complete explanation of their function.

They have shown that two different sets of reflexes modify the tone of skeletal musculature. As has long been known the labyrinth reinforces extensor tone of the body musculature. But, further, in the decerebrate animal, after bilateral section of the eighth nerve, the tone of skeletal musculature may be modified by rotation of the head. The extensor tone is inhibited on the side to which the vertex is turned. This effect has been proved to be due to proprioceptive impulses from the muscles of the neck. Therefore tonic labyrinthine and neck reflexes ("standing reflexes") interact with the prespinal reflex arcs already described, and modify the tone of skeletal musculature. It is interesting to note that Walshe

demonstrated the presence of the tonic neck reflexes of Magnus and de Kleijn in the stage of decerebrate rigidity in the case to which reference has already been made.

Langelaan (29) has shown that labyrinthine reflexes compensate for loss of the sympathetic innervation of the hind limb of the frog. He proves that the effect is due to the dominance of the labyrinth of the opposite side to that on which ramisection is performed. After a few weeks the effect of this dominance is to cause flexion of the hind limb on the operated side and extension of the intact limb.

This increase of contractile tone in the flexors of the limb on the operated side obscures the loss of plastic tone following the operation. Loss of plastic tone becomes evident only when the labyrinthine reflexes are exhausted, or after the frog has remained suspended quietly for a period of 15 minutes. This compensation following sympathetic ramisection is also evident in the wing of the fowl. After a period of 2 months the droop of the wing is no longer evident until the impulses through the accessory pathways for the modification of contractile tone are cut off by keeping the bird at rest (21).

It is a noteworthy fact that decerebrate rigidity persists in the absence of the cerebellum (Sherrington, 47) unless Deiters' nucleus be injured in the process of removal (Thiele, 53). Now Magnus and de Kleijn (35) have shown that tonic labyrinthine reflexes may be performed by the brain stem in the absence of the cerebellum. Ingvar (25) points out that this does not exclude the possibility that, in the intact animal, the cerebellum is a higher controlling organ beneath which the reflex mechanism subserving body-attitude is laid down in the brain stem. In the light of the observations of Weed (65), who regards the cerebellum as an important, if not essential, part of the reflex mechanism responsible for decerebrate rigidity, Sherrington (50) concludes that though the nervous mechanism for reflex standing does not require the cerebellum for its crude performance, this structure "commonly lends it a large amount of support and doubtless of refined adjustment and correlation too." It will become apparent later that the cerebellum is the organ through which the cerebral cortex exerts its influence upon the reflex arcs subserving posture. When the cerebral cortex is destroyed, the influence of the cerebellum is automatically removed also.

HIGHER LEVELS OF ACTIVITY CONTROLLING THE PRESPINAL REFEX ARCS RESPONSIBLE FOR MUSCLE TONE

1. Mid-brain. Magnus (34) has shown that in animals, such as the rabbit, cat, dog and monkey, the whole of the cerebral hemispheres including the corpora striata may be removed and the tone of skeletal muscle remain of normal intensity. Nor is the tone altered when the brain stem is transected caudal to the thalamus. Such a "mid-brain" animal, unlike the decerebrate preparation, is capable of a great variety of reflex activities as walking, running and jumping. It can right itself if overturned, the head at once resuming its normal posture. These are the "postural reflexes" of Magnus (cf. Walshe, 54). Obviously, therefore, in these animals, the mid-brain provides an important part of the nervous mechanism utilized in the regulation of posture. It is when this region is taken away that release of the prespinal reflex arcs takes place to produce decerebrate rigidity. For instance, in higher forms, at least, as Magnus's observations upon the monkey reveal, the connections of the visual pathway with the mid-brain play an important part in the nervous regulation of posture. Tectobulbar connections therefore control the prespinal reflex arcs in these forms. Moreover, decerebrate rigidity develops after the removal of the red nuclei, and as Walshe (57) mentions, "It seems as though removal of the greater part of the red nucleus is an essential preliminary to the development of rigidity." In this process rubroreticular fibers, which in man have attained special importance, are severed. The cells of the substantia nigra are also known to send axones to the tegmental region of the brain stem.

2. Corpus striatum. In view of prevailing conceptions it is noteworthy that in the animals described by Magnus the postural reactions are carried out by the mid-brain in the absence of the corpus striatum. It would,

however, be unwise to argue that in man the mid-brain structures exhibit this independence of the corpus striatum, for the principle of the shifting forward of function in the nervous system must not be lost to sight in this connection. Moreover, as Walshe (54) points out, it may well be that the physiological value of the corpus striatum is only adequately expressed in the presence of voluntary activity. In such a case the symptomatology of lesions of the corpus striatum, with the cerebral cortex intact, will be different from the experimental results of complete removal of both the cerebral cortex and corpus striatum.

For these reasons the observations of Magnus that "thalamus" and "mid-brain" animals exhibit tone of normal intensity and distribution cannot unreservedly be applied to man. It is possible that the corpus striatum in man, with the cortex intact, controls through the intermediation of sub-pallidal nuclei, as the substantia nigra, the sympathetic prespinal arc subserving plastic tone. To study this point I have removed the corpus striatum on one side in birds (21), employing the domestic fowl and the sea gull for this purpose. Birds represent a widely divergent group from mammals. In birds the corpus striatum has attained a relatively enormous importance both structurally, and functionally. The operation is easily performed on birds because the corpus striatum constitutes, except for the septum and a small superficial area of cortex, the entire cerebral hemisphere. Further, in removing the corpus striatum, which is readily accessible because it forms the greater part of the surface of the hemisphere, the cerebral cortex may be lifted up and left in communication with the septum. In this way the tractus cortico-septo-mesencephalicus is left intact.

This operation produces rigidity of all the limbs. Standing is not evenly maintained due to rigidity of the hind limbs. On this account in sea gulls a tendency to rise on the toes is constantly exhibited and the bird does not maintain any given position for long. Birds in this condition often squat down, presumably to avoid balancing on the rigid limbs. The wings are also rigid and here the nature of the rigidity may readily be studied. The wings are sometimes maintained in a position somewhat higher than usual so that the adjacent borders are almost in contact with one another. The rigidity maintains its intensity during passive movement, and on account of its rigidity the wing remains fixed in the new position assumed. This occurs even though the position be so abnormal, as when the wing is folded over the mid-line of the back, that the fibrous structures contained within are put upon the stretch. Dependent positions are maintained equally well. Both wings exhibit this phenomenon after the unilateral operation, but the rigidity is greater on the ipsilateral side. The rigidity is responsible for slowness of movement especially on the ipsilateral side. This is readily seen on watching the movements of the wing during attempted flight while the bird is held captive in the hand. A greater effort is necessary to carry the wing through a smaller range of upward movement than on the less affected side; increased effort marks downward movement also and the wing seems to overshoot the position at which it normally ends. These alterations in the nature of the movement of the wings are greater on the ipsilateral side, so that the flight of such a bird, when released, is always in a circle, the bird tending to fly toward the more affected side.

This diffuse muscular rigidity is strongly reminiscent in an exaggerated form of the condition of the wing already described, in which, after the removal of contractile tone, plastic tone is accessible for independent study. I cannot avoid the deduction that increased plastic tone in both flexor and extensor muscles of the wing is responsible for the diffuse muscular rigidity which follows the removal of the corpus striatum in birds. This element of tone is so enormously increased that manifestations of the presence of the contractile component are in the background.

The condition of rigidity of the wing of birds above described is remarkably similar to Parkinsonian rigidity in man. Its diffuseness, resistance to stretching, and the tendency for fixation of the muscle at any length passively imposed upon it, are common to the two conditions; and in both conditions pov-

erty and slowness of voluntary movement, which are probably due in part to the underlying phenomenon of rigidity (cf. Walshe, 55, p. 102), are notable concomitants.

Removal of the influence of the sympathetic innervation by section of the cervical sympathetic trunk caudal to the brachial plexus abolishes the rigidity of the wing. This property, like normal plastic tone, is subserved therefore by the sympathetic system. It is difficult to escape the conclusion that the basis of the rigidity following lesions of the corpus striatum is increased plastic tone which is exhibited in all muscle groups, and that this is due to removal of control from the sympathetic prespinal reflex arc which maintains the plastic tone of normal skeletal muscle.

Elsewhere (18, 19) I have called attention to the fact that morphology lends support to the view that the corpus striatum is a higher sympathetic level of activity. Ariëns Kappers (3) says: "Visceral disturbances also may occur (liver, bladder) in disease of the corpus striatum and that sympathetic functions have been found to exist here is not so strange in connection with the fact that the primitive striatum develops near the frontal end of the sulcus limitans which according to several authors (cf. Herrick) ends in the preoptic recess. Moreover, we know from the researches of Boeke, Dusser de Barenne, Agduhr, and de Boer, that also in muscle tonus sympathetic fibers may act a part."

The different manifestations of excess of plastic tone in those cases of spastic paralysis which resemble experimental decerebrate rigidity, and in the condition of Parkinsonian rigidity, are capable of reconciliation. The fundamental difference between the two conditions is that, while plastic tone is increased in both, contractile tone is also exhibited in excess in spastic paralysis while it is not greatly in evidence in Parkinsonian rigidity. Contractile tone is selective in its incidence, and the plastic tone of the antagonists of the muscles selected by it is, to a very varying degree, reciprocally inhibited. In Parkinsonian rigidity this selective incidence upon muscles, and consequently the selective inhibition of plastic tone in the antagonists, are absent. In spastic paralysis resistance to passive movement is considerable till the position imposed upon the limb by contractile tone is overcome, when the resistance becomes less. A combination of contractile and plastic tone is responsible for the initial position in spastic paralysis. The posture assumed in Parkinsonian rigidity is due to plastic tone only exhibited in agonists and antagonists and therefore resistance to passive movement is the same throughout the whole range of movement. The fact that postural reactions and intercurrent reflex movements are not exhibited in Parkinsonian rigidity as in spastic paralysis, is a further indication that somatic activities, which include contractile tone, are in abeyance in this condition. The mechanism which inhibits plastic tone in order that a movement may be performed or to allow a new posture to be assumed is no longer active. This effect is probably the cause and not the result of the rigidity. That is to say a predominant function of the corpus striatum is to regulate plastic tone. From a consideration of the other effects of corpus striatum lesions it seems that this regulation is especially in the interests of automatic and associated movements, and of emotional expression. These functions are no doubt impaired by the lesion; the rigidity itself may limit these activities still further.

It remains to be proved that the rigidity of paralysis agitans and allied conditions is subserved by a proprioceptive mechanism in order to establish completely the identity of the tendency in this condition to fixation of the muscle at any length imposed upon it, with the "lengthening" and "shortening" reactions.

In the first place it must be borne in mind that the sympathetic reflex arc subserving plastic tone is not necessarily at the same level as the somatic connections. Therefore, in posterior root section, contractile tone may be affected without removing plastic tone (Fig. 1). In Sherrington's deafferented specimens all the posterior nerve roots connected with the limbs were resected. In his experiments on the fore limb (47, p. 323) of the cat he removed the posterior nerve roots of the lower cervical nerves and the first thoracic nerve. In the case of the hind limb (49, p. 125)

he removed usually the fourth and fifth lumbar nerves. Now Langley (30, p. 637) has found that the white rami of the sympathetic system in the cat extend from the first thoracic to the fourth lumbar segments. Therefore in both operations Sherrington removed any afferent sympathetic fibers entering the spinal medulla at the level of the highest and lowest white rami respectively.

Surgical operations upon the posterior nerve roots have necessarily been less complete than is possible under experimental conditions.

Leriche's cases (quoted by Walshe, 55) in which posterior root section was performed for the relief of paralysis agitans are evidence of this. In one case the fifth, sixth, and eighth cervical posterior nerve roots were divided. In this case the rigidity was undiminished. Obviously, however, the sympathetic afferent connections of the skeletal muscle of the limb were left intact by this operation because the first thoracic posterior nerve root was not attacked. Therefore this case does not disprove that rigidity is maintained by a proprioceptive mechanism. The first principle of posterior root section in man should be to include the first thoracic posterior nerve root in the case of the upper limbs, and first or second lumbar posterior nerve roots in the operation for the lower extremities.

However, Walshe (loc. cit.) has recently brought forward strong evidence that the rigidity of paralysis agitans is due to the activity of a proprioceptive reflex mechanism. He has shown that injection of 1 per cent novocain into the muscle at its motor point causes rigidity to disappear. While admitting the possibility that this effect may be due to direct action upon the muscle, he shows convincingly that the balance of evidence is in favor of the view that the afferent nerve terminations are affected.

Walshe's investigations upon the rigidity of paralysis agitans beautifully illustrate the fact that the tremor exhibited in this condition and the rigidity are subserved by two different nervous mechanisms. For although novocain abolishes rigidity the tremor is totally unaffected. The indications are that impulses through the cerebrospinal tracts are involved in the production of spontaneous tremor for it disappears after hemiplegia (55, 67).

This is in accord with the results of sympathetic ramisection in this condition. The rigidity is markedly diminished, voluntary power is increased, and movements are more ample and rapid, but the tremor is not appreciably affected when well established. But a patient with Parkinsonian rigidity without tremor, as for instance as a sequela of encephalitis lethargica, may derive sufficient benefit to justify the operation.

In a recent paper McAlpine (36) has described a patient who, as sequela of epidemic encephalitis, developed Parkinsonian rigidity on the right side and a condition strongly resembling decerebrate rigidity on the left side. According to views advanced here, the diffuse muscular rigidity on one side was due to a generalized increase of plastic tone, lack of selective incidence being due to the absence of increase of contractile tone. The rigidity on the other side, however, was sometimes flexor and sometimes extensor. Therefore, contractile tone was present and acted selectively on different groups of muscle at different times. Plastic tone was also enhanced in the upper and lower limbs of this side. It was exhibited by the presence of the "lengthening" and "shortening" reactions. It was shown to the greater extent in the flexor and extensor muscles at any particular time according to the selective incidence of the contractile tone at the time. In the erect posture tone predominated in the extensor muscles of these limbs. Since the tone responsible for this decerebrate attitude consists of the two normal components of tone, the term plastic tone alone is clearly inadequate to describe the condition. Sherrington's term "postural tone" may be used for this purpose. Contractile tone reflexly imposes the position upon the body and plastic tone maintains this position once it is assumed. On passive movement the characteristic "lengthening" and "shortening" reactions indicating the presence of plastic tone are elicited.

3. Cerebral cortex. In a natural attitude such as standing contractile tone is responsible for selective action upon antigravity muscles

and plastic tone fixes the length of the muscle fibers necessary to maintain this position. To accomplish voluntary movement from this position the prespinal reflex arcs responsible for postural tone must be controlled by the cerebral cortex. Evidence is accumulating that the cerebral cortex not only causes contraction of the appropriate muscle groups by way of the cerebrospinal tracts, but inhibits the reflexes responsible for postural contraction. It effects this purpose through the intermediation of the cerebellum.

Sherrington (47) and Loewenthal and Horsley (33) suggested the presence of such a cerebellar pathway. These observers located the inhibitory area of the cerebellum in the anterior part of the superior vermis. Weed (65) confirmed this observation and elucidated facts which pointed to the presence of an inhibitory pathway from the cerebral cortex to cerebellum. He found that in the decerebrate cat stimulation of the medial one-fifth or one-sixth of the cerebral peduncles at the level of transection of the mid-brain led to the entire disappearance of the rigidity of the ipsilateral limbs and diminution in the contralateral. This did not occur after removal of the cerebellum. Further experiments showed that the path from the peduncle ascended to the cerebellum by way of the contralateral middle cerebral peduncle.

Warner and Olmsted (64) have traced the origin of this inhibitory tract to the frontal region of the cerebral cortex. When the motor area was cut away no increase of extensor tone was observed on either side of the body. Definite rigidity developed at once in the contralateral fore and hind limbs when the frontal area was removed. This observation is of great significance in view of the fact that, in man, pure cortical lesions of the pyramidal tracts do not produce spasticity. On the other hand lesions of the area of the frontal lobe from which the frontopontine tracts originate (Campbell) are associated with a condition of "tonic innervation" expressed as inability to relax a contracted muscle group (cf. Wilson and Walshe, 67).

Warner and Olmsted have elucidated the course of this tract arising in the frontal region by studying the inhibition of rigidity obtained by electrical stimulation of the cut surface of the brain in various situations. They found that the inhibitory effect of the tract is bilateral but predominantly contralateral. The tract passes from the frontal lobe through the medial part of the internal capsule. Caudal to the level of the superior colliculi it crosses, in greater part at least, to the other side of the brain stem. It continues to the cerebellum by way of the middle cerebellar peduncle. The inhibitory tract is therefore frontopontocerebellar in its connections.

Warner and Olmsted state that when this tract is stimulated a limb exhibiting extensor rigidity goes "limp and flaccid." Miller and Banting (37) describe the effect of stimulation of the anterior surface of the vermis as being "immediate and general relaxation of the rigidity." Obviously the inhibition affects both contractile and plastic components of tone which are enhanced in degree to produce decerebrate rigidity. The frontopontocerebellar tract, therefore, inhibits the effect produced by the somatic vestibulospinal and sympathetic pontospinal tracts. When this tract is ineffective the power to relax the muscles after being employed in muscular effort is defective. In the absence of a case purely of this nature in Dr. Royle's series, it is interesting to note that the effect of sympathetic ramisection improves the power of relaxation of contracted muscles in spastic paralysis. It is to this fact that the increased control and rapidity of effecting voluntary movement are due. The patient need no longer inhibit plastic tone. His cortical control is mainly concentrated on executing movement.

It is worthy of note that tumors of the middle lobe of the cerebellum give rise to fits of a tonic character in which the extensor attitude of decerebrate rigidity is assumed (cf. Hughlings Jackson, 17). Sherrington (47) found that a rigidity somewhat similar to that ensuing on removal of the cerebral hemisphere set in after median section or ablation of the cerebellum. He was not convinced that the two conditions were identical. Thiele (53, p. 369) however, regarded the bilateral rigidity which followed removal or bisection of the vermis as being like decerebrate rigidity. He

explained it as being due to loss of the inhibitory control of the vermis over the nucleus of Deiters. No doubt also the pontospinal tracts are released from control. It will readily be seen that the only effect of sympathetic ramisection upon tonic extensor fits following interference with the frontopontocerebellar pathway is to diminish the degree of rigidity during the extensor spasms. Since contractile tone remains practically unaffected after this operation the extensor attitude will still be assumed. This is another instance of posture alone not being an indication for ramisection.

The fact that the cerebral cortex employs the cerebellum as an intermediate organ through which it exerts an inhibitory influence over the postural reflex arcs of the brain stem is of great general significance. It confirms the suggestion of Walshe (60) that "the cerebellum is the organ through which the cerebral motor cortex influences postural activities and regulates posture in the interests of coordinated purposive movement." "It may be," he proceeds, "the subordinate mechanism employed by the cerebral cortex in the refined correlation of posture and movement." This view indicates that the cerebellum is employed by the cortex in the performance of active movements also. It reinforces postural tone in order to maintain the attitude of the body assumed during the performance of the movement initiated and executed by motor impulses which have their origin in the cerebral cortex.

In 1900, discussing the significance of the cerebrocerebellar pathway which passes through the brachium pontis, Sherrington (48) said: "Thus one and the same cerebral discharge may perhaps pour upon the motor root nerve cells a combination of cerebral and cerebellar impulses." It is on account of the influence of the cerebral cortex in the regulation of posture through the intermediation of the cerebellum that lesions of the cerebellar hemisphere cause incoordination of voluntary movements.

When a voluntary movement is completed cortical impulses reinforce contractile tone to determine the attitude assumed by the body. Plastic tone aids in maintaining this position because the muscle fibers exhibiting it are fixed at their new length. After sympathetic ramisection this accessory contribution is lost but the influence of the cerebral cortex on contractile tone remains. In this connection it is well known that tone is increased by attention (cf. Langelaan, 28, p. 324). Also Dr. Royle has noticed that during the first period of re-education after sympathetic ramisection when the patient's attention is focused on the performance of a voluntary movement, under orders, the cortex greatly increases the amount of contractile tone exhibited in the limb. This increases the difficulty of the patient in performing the movement. On this account gently executed movements are far more effective than considerable effort in this stage of the re-education process.

Evidence is not wanting that plastic tone is of use also during the performance of voluntary movement. Under ordinary circumstances a patient who has been subjected to the operation of sympathetic ramisection cannot detect any disability in consequence of the loss of the sympathetic nerve supply of his voluntary muscles. However, to test this matter closely (21) I have observed the effect of sympathetic denervation after the exercise involved in the flight of a bird. During the flight of a sea gull in which the unilateral operation has been performed, no obvious difference is to be detected in the movement of the two wings. After completing a flight of one hundred meters, however, the position of the wing on the operated side is in marked contrast to that on the normal side. It is drooped and abducted to a remarkable degree although hardly any deviation from the normal position may have been visible prior to undertaking the flight. The explanation of this observation seems to be that plastic tone enables the fixing muscle fibers to follow up the contraction of the active fibers and assist in maintaining the intermediate positions assumed at all stages of the movement. When plastic tone is removed, voluntary effort is increased in order to maintain these intermediate positions against the action of gravity as well as to perform the movement.

It appears, therefore, that in voluntary movement postural tone, made up of a contractile and a plastic component, is first in-

hibited; the "movement" muscle fibers then contract and are assisted in maintaining the advantage gained by the plastic tone of neighboring "fixing" fibers which are passively shortened; and finally cortical impulses determine that contractile tone is exhibited in the muscles whose contraction is necessary to confer the required position upon the body; the length of the muscle when this position is attained is maintained by plastic tone exhibited by "fixing" muscle fibres.

In certain cases of spastic paralysis plastic tone is in excess. This interferes with voluntary activity, because it is imperfectly inhibited at the outset of voluntary effort. When excessive voluntary effort initiates movement the exaggerated degree of plastic tone, which is present in both agonists and antagonists, as Dr. Royle has shown, tends to provide resistance to the execution of the movement by fixing, to an abnormal degree, the length of the muscles of the limb at all the intermediate positions through which the moving part passes. In this way, the effects of diminished voluntary power are enhanced in degree on account of excess of plastic tone, which is no longer adequately controlled by the cerebral cortex. In fact this defective control is not infrequently the greater disability, and on account of it the voluntary motor pathway may be unable to function to the full extent of which it is capable. This disideratum is attained by removing the plastic tone entirely, when the rigidity of the muscles disappears. The result is that the initiation and the execution of voluntary movement are both improved.

Dr. Royle found that one patient, with a gunshot wound of the cerebral cortex, who illustrated the presence of excess of plastic tone to a striking degree before the operation, was able to inhibit the tone of the extensor muscles of the knee following ramisection. He was unable to flex the knee voluntarily, but he could inhibit the tone of the muscles sufficiently to let the leg fall into the flexed position. This was impossible prior to the operation. In other words this patient was unable to inhibit plastic tone. After ramisection he was able to inhibit the contractile component of tone which alone remained. This patient illustrates that the cerebral cortex normally inhibits both components of postural tone and that injury may affect the control over the plastic component to a greater extent than that of the contractile element. This accounts for the marked improvement in control which follows sympathetic ramisection.

CONCLUSIONS

In conclusion, therefore, I wish to emphasize that the basic principle of the operation of sympathetic ramisection is that it removes plastic tone. It is only indicated when plastic tone is in excess and hampers the voluntary activities which have persisted in spite of the central lesion. A study of the nature of the spasticity of the spastic limbs, and an estimate of the anatomical defect of the central mechanism responsible for the condition, must go hand in hand, and only when the physiological indications are discoverable is the operation to be undertaken.

This principle stamped the teaching of the great surgeon who is honored in this annual memorial address. With the wide grasp of knowledge which enabled him to encompass almost every specialized branch of surgery, Dr. John B. Murphy made pioneer contributions to the surgery of the nervous system, and his teaching in this domain is founded upon the basic physiological knowledge of his day. True insight and a fine faith led him to say (38) as early as 1907: "We feel that the nervous system offers sufficient inducement for surgical intervention to demand the surgeon's most careful, systematic, and analytic efforts, both experimental and clinical." The purpose of this address is to combine morphological, experimental, and clinical facts, to demonstrate the physiological principles which should underlie the surgical procedure of sympathetic ramisection.

NOTE.—The cost of the experiments referred to in this paper have been defrayed from the research fund generously donated to the Anatomy Department, University of Sydney, by Mr. George H. Bosch, Sydney.

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THE ACUTE ABDOMEN[1]

By JOHN B. DEAVER, M.D., F.A.C.S., Philadelphia

THE subject of acute abdominal conditions comprises perhaps the most important questions in surgery and medicine. The acute abdomen calls for careful judgment and thoughtful consideration. It is not, as a rule, the result of virgin pathology. In the majority of instances it is an end-result of a chronic pathological process which has probably given evidence of its presence for a more or less prolonged period. More often than not the cases present a history of an antecedent lesion, such as chronic appendicitis, peptic ulcer, cholecystitis, pancreatitis, or hernia. Occasionally the acute abdomen, however, results from conditions not easily recognized even by the most astute and experienced diagnostician. Among such conditions may be mentioned mesenteric thrombosis, acute obstruction due to internal strangulation by an unusual formation, such as a diverticulum, obstruction in an intestinal fossa, obstruction due to hernia through a congenitally large foramen of Winslow. We have recently experienced this last-named condition at the Lankenau Clinic in Philadelphia. The patient was brought to the hospital with all the signs of an acute abdomen; operation was resorted to at once and the patient made a complete recovery.

Acute intestinal obstruction also may be due to a congenital hole in the mesentery. This rare condition has occurred in my experience. It also presented the signs and indications that warrant immediate operation.

The more common causes of the acute abdomen should be recognized without difficulty provided a careful study of the history and a well-conducted physical examination is made, that is, as thorough as circumstances permit.

Permit me to call attention, as I have frequently done on other occasions, to acute intestinal obstruction in a patient who has had an abdominal operation at a more of less remote period. The presence of an abdominal scar in a patient suddenly seized with acute abdominal pain, should at once arouse suspicion of serious trouble, and intestinal obstruction should be in the mind of the doctor. Very often, however, the doctor fails to think of this because the textbook description of intestinal obstruction is in his mind, such as vomiting of stercoraceous material, distended belly, inability to pass gas, etc.; waiting for these signs makes it too late for a curative operation.

The acute abdomen in the absence of an abdominal scar should first, last and always suggest the appendix. At the same time one must ever bear in mind the possibility of incipient pneumonia, especially when the patient is a young child; or in rare instances, a diaphragmatic pleurisy. In the presence of acute upper abdominal pain together with muscular rigidity, rapid respiration, rapid pulse, high temperature and unusually high leucocytosis, pneumonia should be considered in the diagnosis, all the more so if, in addition to the above, the patient has had a chill.

In the majority of cases the acute abdomen is due either to appendicitis, or, in the following order of frequency, to cholecystitis, perforated duodenal or perforated gastric ulcer, acute salpingitis, acute intestinal obstruction, ruptured extra-uterine pregnancy, acute pancreatitis, acute hæmatogenous infection of the kidney, twisting of the pedicle of an ovarian cyst, acute diverticulitis, mesenteric thrombosis, acute salpingitis, etc.

The acute appendix, owing to the different positions it may occupy, can easily simulate other conditions, especially when it is retrocæcal or retrocolic (which is the case in 69 per cent of cases) and extends as high as the gall bladder, thus presenting many of the signs and symptoms of acute cholecystitis. The distinction between the two latter cannot always be made clinically. When the acute appendix occupies its second most common position, in the pelvis, we all know how it resembles acute pelvic disease, and in this position the pain is more likely to be referred to

[1]Read before the George Washington Medical Society, Washington, D.C., April 29, 1924.

the left side of the abdomen; other positions of the appendix are subcæcal; anterior to the terminal ileum, or pre-ileal, posterior to the terminal ileum, or post-ileal, pointing to the left in the direction of the spleen.

On general principles it may be said that in the acute abdomen, with diffuse peritonitis, in the absence of a history that would enable a reasonably sure diagnosis, and in the absence of a localized point which would be a guide for the surgical point of attack, it is the part of good judgment to defer operation, and to place the patient under strict anatomical and physiological rest or, as we term it in the Lankenau Hospital, regulation. In many instances, in the presence of a diffuse peritonitis, or what I take to be such, I have been able to make the diagnosis a few hours after the patient has been on such regulation treatment. This means relieving pain by judicious doses of morphia given hypodermically, commencing with the smallest dose consistent with the severity of the pain and increasing the dose when necessary, washing out the stomach and repeating the washing if necessary, and applying the Murphy drip and an ice bag to the abdomen. I have misgivings in some of these cases as to the diagnosis of diffuse peritonitis, and when I have seen them improve have wondered whether the condition was not a diffuse peritoneal irritation, but even so, the recovery of the patient is the answer to the question. To open the abdomen of a very sick patient, when one has practically no idea of what is wrong, is to my way of thinking and from my experience to say the least, unwise.

If the treatment of the acute abdomen is to succeed, the diagnosis must be made early. It is the peritonitis that so often clouds the picture, and when advanced often makes diagnosis impossible. The first one on the scene assumes the greater responsibility, that is in the early case. It behooves us therefore to be ever on the alert.

The acute abdomen still occupies too prominent a place in mortality statistics. There are various explanations for these unnecessarily high figures. It is with chagrin that we must admit that among the main reasons for this are untimely and unsuitable operations.

What would I have you understand by untimely operations? I can perhaps best make this clear by mentioning operation for appendicitis in the presence of a diffuse peritonitis, a silent belly, and no palpatory evidence of a point of localization. This was wonderfully well expressed by the late Dr. Maurice Richardson as "too early for a late operation and too late for an early operation." This would apply also to acute cholecystitis with diffuse peritonitis. To operate in the presence of acute hæmorrhage from the stomach without very strong evidence that it is due to chronic ulcer is also untimely.

What would I have you understand by unsuitable operation? An operation for acute appendicitis with circumscribed peritonitis and abscess formation in which the opening is made into the free peritoneal cavity is an unsuitable one if the best interests of the patient are to be served. In appendiceal abscess, where the mass is in the neighborhood of, or to the outer side of or behind the cæcum or the descending colon or in the pelvis, the two most common positions for the appendix, it is my practice, in the case of the former, to incise the abdominal wall well to the outer side of the mass, cutting down on the transversalis fascia through which I work in exposing the peritoneum, when if I am able to feel a soft point indicative of the presence of pus, I open the peritoneum well down and under the mass as it were. When the peritoneum is thus exposed, by sliding the fingers beneath the mass, one can frequently lift it up, thus making it very clear where to attack the abscess with the least risk. We are all familiar with the œdematous tissue so commonly present in these advanced abscess cases.

In appendiceal pelvic abscess the same route of approach is followed, with the exception that the incision does not extend so high and is carried down lower. When the abscess, in either situation, is evacuated and carefully sponged so as to present a clear field, the appendix may be removed, if it is deemed advisable. I may say here it is not my practice to take out the appendix in all these abscess cases. But if I do not take it out at the time of treating the abscess, I certainly

advise its removal when the patient has recovered from the operation.

An operation for perforated peptic ulcer, where merely closing the ulcer would not be a perfectly safe provision against leakage, is likewise an unsuitable operation unless a gastro-enterostomy is also made. Let me add that in perforated ulcer of the duodenum favorably situated for resection, but where the opening cannot be made water-tight by closure with suture and omental reinforcement, resection should be done, provided of course that the case is an early one. I have seen leakage take place 4 or 5 days after operation in such cases, followed by death. I am glad to say that I have not had this occur in my own practice; but nevertheless it is one of the possibilities the surgeon, I care not who he may be, must face. An operation for acute intestinal obstruction superimposed upon a chronic obstruction due to a neoplasm, which would include excision of the growth, is also an unsuitable operation.

On the other hand, the high mortality of the acute abdomen is partially due to the lack of intimate knowledge of living surgical pathology, and partly because of too great a reliance on laboratory findings, which do not always correspond to the operative findings; and finally also to hesitancy in adopting radical measures in the hope that the patient may recover under what is called conservative treatment. Radical treatment under these conditions, however, is truly conservative because it conserves life. A case in point to illustrate my contention that too much reliance is placed on laboratory findings, is when the attending physician has made a diagnosis of appendicitis and postpones operation until he has made a blood count. There is of course no objection to this provided the loss of time in getting the count does not add to the danger of the situation. But this is not likely. When, however the count having been made, shows no high leucocytosis, and the doctor allows this to influence him against operation, he assumes a terrific responsibility. The result of this attitude is that many cases of appendicitis are brought to operation when the pathology is so extensive that not only does recovery become questionable, but operative sequelæ of an unpleasant kind may be expected. The late Dr. John B. Murphy said that for every death from appendicitis somebody has been to blame. I have frequently been called on the telephone to hold myself in readiness to operate if the blood count, not yet taken, should be high. This order, or I should say disorder, of affairs has cost many a life. I venture to say, without incurring the risk of too much assurance, that no one is in a much better position than myself to realize this as a fact. When to operate in acute appendicitis, depends, as I have so often stated, not upon the blood count, but upon the physical examination and the condition of the patient.

Let me digress for a moment to say that frequently when I am called in to see a case of acute appendicitis practically recovered from the attack, and I advise removal of the appendix, when recovery is complete, the doctor in attendance advises waiting for another attack before having the patient subjected to operation. This I believe is almost criminal, for I have seen many patients perish in the subsequent attack. Who has been to blame? Unfortunately, the medical man, and not the surgeon, is too often the consultant in acute appendicitis; this is as unfortunate perhaps as having the surgeon and not the medical man the consultant in a case of typhoid or scarlet fever. The late Dr. Osler said that in acute appendicitis the surgeon can be called too late but never too early.

Among the untoward events following delayed operation—an event which does not happen after early operation—is a fæcal fistula. One of my senior house surgeons (Dr. Maurice P. Charnock), in the Lankenau Clinic, has just completed for me the records in the last two hundred fæcal fistulæ occurring among 4,063 late cases of acute appendicitis, showing that 1 in every 20 cases is exposed to this sequel, to say nothing of the occurrence of other sequelæ.

Acute diverticulitis of the sigmoid very closely resembles acute pelvic appendicitis, so much so as to make the differential diagnosis at times almost if not altogether impossible. Acute abdominal pain and the presence of a mass in the left lower abdomen should suggest

the diagnosis of diverticulitis (diverticular inflammation). The history of the diverticular conditions differs from that of appendicitis in that the patient is more likely to complain of constipation, much intestinal flatus and more or less discomfort in passing gas, as well as soreness referred to the lower left abdomen. Rectal examination in both cases is important and in diverticulitis is more likely to demonstrate a mass than in appendicitis, although in the majority of cases of diverticulitis, the diverticulum, with the surrounding inflammatory exudate, is situated too high up to be felt per rectum. Here also the diagnosis may be clouded by the presence of a peritonitis. Occasionally, in diverticulitis there will be rectal tenesmus, which may also be present in acute pelvic appendiceal abscess; but this does not occur often enough to make it of much moment in the differential diagnosis.

Acute perforating peptic ulcer, which occurs in from 15 to 20 per cent of ulcer patients, is another common cause of the acute abdomen. This is more frequent with the chronic duodenal than with the chronic gastric ulcer, while perforation of a marginal ulcer, though rare, may also take place. Perforation also occurs in the acute round ulcer. All of them, however, present practically the same symptoms and signs, so that the exact diagnosis of the type of ulcer is of little moment until the abdomen is opened. The surgeon not familiar with the operative technique for the non-perforated marginal ulcer may find difficulty both in locating and in correcting the same. If a patient with a history of having had a gastro-enterostomy becomes the subject of an acute abdomen, perforation of a marginal ulcer should be thought of, for, unfortunately, marginal ulcer still remains the most serious sequel of a gastro-enterostomy.

The acute abdomen due to an acute perforated peptic ulcer should always be recognized by anyone who has once seen this condition. It is marked by sudden onset of terribly acute abdominal pain which is immediately followed by pronounced, boardlike rigidity of the abdominal muscles (once felt never forgotten), and the inclination of the patient to remain immovable on his back with the legs drawn up; in other words, the patient does not attempt to change his position, fearing his pain will be made worse. I, as well as my house surgeons, have made this diagnosis many times by simply palpating the abdominal walls. I often wonder if this diagnosis is not missed because the doctor who first sees the patient did not palpate the belly. The history in these cases plays a small part, because the patient is so obsessed with the idea of obtaining relief that he forgets the past, in fact, does not even want to be asked about it. The history is best obtained during recovery after the operation. The frequent occurrence of acute perforation of a peptic ulcer should keep any right-minded doctor from advising medical treatment for chronic non-perforating peptic ulcer, and convince him of its uselessness from the standpoint of cure. I am very positive in the stand I am taking on this subject because of the many catastrophies I am constantly being confronted with. Chronic peptic ulcer, like appendicitis, I think is the surgeon's province. The doctor who is on his job and sees the case early can add much to his own joys and that of the surgeon, but if he is not on his job, trial and tribulation await him as well as the surgeon.

It certainly is an indisputable fact that a knowledge of living surgical pathology better enables us to recognize and interpret signs which otherwise might be inconclusive and hazy. To illustrate this point, let me take a case of carcinoma which is not definitely diagnosed before operation. A working knowledge of surgical pathology helps very materially in deciding the very important question as to what to do. To start to remove a growth about the nature of which one is not reasonably clear would too often mean that the operation once begun must be completed; otherwise, the patient will perish, if not immediately, then later from loss of blood. A working knowledge of the living pathology will tell whether or not to attempt removal.

I recently operated upon one of my colleagues who was intensely jaundiced with the severe itching that frequently goes with jaundice. He was emaciated, careworn in appearance, with no desire for food. The preoperative diagnosis was carcinoma of the pancreas. On opening the abdomen I saw a hugely

distended gall bladder and felt a mass in the head of the pancreas and the entire pancreas was moderately hard, so I quickly made a cholecystoduodenostomy and nothing more. Some of the medical friends of the doctor who were present took exception to my method because I did not make a more careful and prolonged examination, also because I did not take a specimen for examination. The operative diagnosis wavered between chronic pancreatitis and carcinoma, in favor of the former, since the entire pancreas was moderately, but not stony hard, with a mass in the head of the organ. The patient 6 months later is greatly improved, is gaining strength and weight and is entirely relieved of jaundice. My decision was quickly made, from what I had learned in my many studies of living pathology.

Acute pancreatitis should be thought of in the presence of sudden, violent abdominal pain referable to the epigastrium or the adjacent portion of the abdomen followed by syncope or shock, persistent vomiting of small amounts of bilious material, subnormal temperature and a rapid, weak pulse, cyanosis of the face and extremities, swelling of the epigastrium, which is tender especially to deep pressure. If acute pancreatitis cannot be ruled out in the differential diagnosis, operation should immediately be done, when if this condition is found the surgeon should deal only with the pancreatic lesion and not attempt to investigate the biliary passages. This, in my experience, promises most for the patient. I am aware that in the past these cases have been more often diagnosed as acute intestinal obstruction than acute pancreatitis. I can understand this error in the presence of an acute obstruction by a volvulus or an internal hernia, but not in the ordinary forms of obstruction. While speaking of intestinal obstruction, let me say in passing that the first thing to do in dealing with this emergency is to look for a strangulated hernia.

The acute traumatic abdomen is seen often enough, particularly in our large hospitals, to warrant consideration in this discussion. There are two kinds of traumatic abdomen: the one where the abdominal walls have been penetrated and the other where they show no evidence of injury The former is the more common in civil practice, but less common than formerly. In the treatment of the acute traumatic abdomen with penetration of the abdominal wall, with or without serious symptoms, it is a sound surgical principle first to make sure that the peritoneal cavity is not involved, and this can be done only by exploration. No harm can result from this practice, while to omit it, may entail serious risk to life. In the non-penetrating case in the absence of symptoms or signs, expectant treatment may be resorted to. But even when the abdominal wall shows no injury and there is no reasonable certainty that there is no intra-abdominal injury, the abdomen should be opened. This may seem rather radical, but permit me to say that my experience bears me out in this statement, for I have oftentimes operated in such instances against advice, and have found several small hæmorrhages, or a divided intestine, and the like.

I have known patients to bleed to death where there was a temporary arrest of the hæmorrhage by pressure of a blood clot. This is indeed a calamity.

Internal hæmorrhage of the non-traumatic acute abdomen often results from bleeding from a ruptured tubal pregnancy. It is well known that rupture of the fallopian tube at the uterine junction is very serious; operation cannot be done too early. A famous Philadelphia pathologist, and at one time coroner's physician, was in the habit of telling his students that the cases with rupture at this point were the ones on which he operated, while rupture distal to the uterus, including tubal abortion, were the ones operated upon by the surgeon. Where there are signs of ruptured tubal pregnancy I always operate at once, and rarely have to give, even in very bad cases, an infusion of salt solution. One of the surgical principles in the presence of a bleeding vessel is to tie the vessel. I cannot understand the practice of waiting for the patient to react when he is bleeding, that is to say waiting for the formation of a blood clot, or mass of blood clots to arrest the bleeding. This is not the practice of the general surgeon but of the specialist, and I have no hesitancy in saying that the practice courts disaster.

In endeavoring to decide for or against the possibility of intra-abdominal injury the pain is not so much of a guide, as the character of the pulse and the rigidity. If after rest in bed and recovery from the initial shock the early rapid pulse of low tension persists, suspicion of hæmorrhage should be aroused.

Abdominal protective rigidity with localized tenderness is an unmistakable sign of intra-abdominal injury. If in addition there is flatness on percussion, with movable dullness and the rapid pulse and other signs of internal bleeding, operation cannot be done too soon. The blood pressure and the blood count should be taken at once and preparations made for blood transfusion. I believe it to be a loss of valuable time to wait too long for the patient to react. One word more as to abdominal rigidity. It may be either generalized or localized over a small area. The latter often occurs in late cases of gunshot wound where a lateral wound has involved only the colon and abscess is in process of formation. From war surgery we learned that absence of rigidity is considered an unfavorable sign, since it is usually associated with extensive lacerating lesions of the small and sometimes the large intestine, in cases that come under observation from 10 to 12 hours after being wounded.

The absence of vomiting should not mislead one to believe that there is no internal injury. If the injury is received on an empty stomach, vomiting may be omitted from the picture.

In opening the acute abdomen the incision is usually a low one through one or the other rectus muscle. After the muscle has been split some idea may at once be gained of what one may expect to encounter. Tension of the transversalis fascia and of the underlying peritoneum may be due to gas, but it may also be due to intestinal distention; discoloration of the extra-peritoneal tissue should suggest retroperitoneal rupture of some part of the bowel, and if the transversalis fascia is bile stained, rupture of the gall bladder or the duodenum should be thought of. A dark purple hue to the peritoneum indicates intraperitoneal effusion of blood. It is for this eventuality that one should be on guard, for with the opening of the peritoneum there may be a gush of blood, and the release of a clot may cause additional hæmorrhage.

In exploring the traumatic abdomen, when the source of hæmorrhage is not apparent, it is good practice first to examine the liver and the spleen, and if these are not involved, to proceed to look for injury to the outer coat of the stomach or of the intestine, or for lacerations of the great omentum, the mesentery, the gastrohepatic omentum, or the mesocolon, etc., or for possible rupture of a retroperitoneal organ such as the kidney or the pancreas, or of some of the retroperitoneal vessels.

The liver is more often injured by trauma than the other organs because its tissue lacks elasticity. While very often immediately fatal such injury is not necessarily so, but immediate operation is essential. The incision is usually made on the right side as the right lobe of the liver is injured about five times as often as the left lobe. Lacerations in the liver can be sutured without much difficulty except on its inferior surface where packing must be resorted to. A search for other injuries can be rapidly made; the right kidney especially should be examined as, owing to its proximity to the right lobe of the liver, it is apt to sustain concomitant injury.

Traumatic rupture of the spleen usually occurs in young people probably because of the elasticity of the costal muscles. It can scarcely be diagnosed except by early signs of hæmorrhage and the history of the accident. Peritonitis sets in earlier than in rupture of the liver. Conservative surgery of the spleen is a difficult matter, especially in the traumatic ruptured spleen since the lesions may be multiple, so that splenectomy is the best method and attended with the least risk to life.

I will not weary you with details in other possible intra-abdominal injuries. Suffice it to say that the traumatic like the non-traumatic acute abdomen is an emergency case, and surgery is in most instances the conservative procedure. One of the advantages of the experiences of the late war in the treatment of intra-abdominal trauma was the removal of the hesitancy to explore the abdomen. This brought about a 10 per cent reduction in the mortality of cases treated late compared with those treated early in the war.

RENAL TUBERCULOSIS DURING PREGNANCY

By WILLIAM E. STEVENS, M.D., F.A.C.S., San Francisco
From Stanford University Medical School

ALTHOUGH pulmonary tuberculosis is not uncommon, renal tuberculosis is rarely found as a complication of pregnancy. Very few cases are recorded in the literature and no one, with the exception of James Israel who mentions 2 cases, has reported the personal observation of more than 1 case. Tuberculosis of the kidney was seen but once in the last 3,103 patients admitted to the obstetrical department of Stanford University Medical School.

There seems to be a general impression that the kidneys are more capable of resisting tuberculous infection during pregnancy. I do not consider this to be the correct explanation of the infrequency with which renal tuberculosis is diagnosed during this period but believe that many cases are overlooked because of the customary frequency with which urinary disturbances occur during gestation, and the failure to make a proper urological examination. The urine of every woman should be examined prior to marriage and at frequent intervals during pregnancy. If pus or blood is present a thorough investigation should at once be made in order to determine their source. Graebke reports a case in which pus, blood, and tubercle bacilli were found in the urine from the left kidney during pregnancy. Nephrectomy failed to reveal any evidence of tuberculosis. Following parturition numerous examinations showed that both kidneys were functionally normal and no tubercle bacilli could be found in the urine. He concluded that tubercle bacilli can pass through the kidney without causing tuberculous modification. The above triad of symptoms, however, is so unusual in the absence of renal tuberculosis that I believe that this observation may be safely disregarded.

The deleterious effect of pregnancy upon tuberculous infections in general has long been recognized and tuberculosis of the kidney is not an exception to the rule. This is to be expected because of the impairment of drainage so often present and because of the increased elimination which is demanded of the kidneys during gestation. Many pathological conditions, for instance, a colon bacillus pyelitis, which have been in a quiescent state, now become activated and resemble acute infections. The following 2 cases, the first seen in consultation with Dr. Chester B. Moore and the second in the Women's Clinic of the Stanford University Medical School, together with a number reported in the literature, serve to illustrate the soundness of this contention.

Case 1. A patient, 22 years of age, in the fifth month of pregnancy complained of frequent urination. A large number of pus cells had been found in her urine 9 months previously. Glands had been removed from her neck when she was 10 years old. Examination of a catheterized specimen of bladder urine revealed many pus cells and a few acid fast bacilli. The function of the right kidney was diminished and the urine contained a large number of pus cells. The left kidney urine was microscopically negative. The guinea-pig inoculated with urine from the right kidney was positive for tuberculosis, the one with urine from the left kidney was negative. Consent to operate was not obtained until after confinement. At delivery 4 months later, Dr. Moore found the use of high forceps necessary because of the persistent right occiput posterior position of the head. The child was normal except for a small infected wound on the left side of the neck from which tubercle bacilli were recovered. This healed in 3 weeks but in a short time a gland on the same side of the neck suppurated. Examination of the discharge revealed a large number of tubercle bacilli. The baby died 8 months later of tuberculous meningitis. The mother is apparently free from tubercular infection at the present time, 20 months after nephrectomy.

Case 2. A patient, 30 years of age, in the second month of pregnancy, entered the Stanford Women's Clinic, complaining of frequent urination, pain in the right lumbar region radiating to the bladder and blood in the urine. These symptoms were of 1½ years' duration but had increased in severity since conception. Both of her parents and two sisters had died of tuberculosis. Cystoscopic examination revealed a much diminished bladder capacity, an inflamed bladder mucosa and an irregular, eroded

right ureteral orifice. The guinea-pig inoculated with the right kidney urine was positive for tuberculosis, that inoculated with urine from the left kidney was negative. Marked improvement followed nephrectomy, the patient gaining 20 pounds in weight. Abortion occurred 2 months later. Four months after operation tuberculosis of the remaining kidney was found.

While a correct diagnosis is obviously of great importance, the question of treatment is of more interest in the consideration of renal tuberculosis during pregnancy. I am in accord with the majority of urologists who have written upon this subject in the opinion that, regardless of pregnancy, nephrectomy is always indicated as soon as the diagnosis is made if the infection is limited to one kidney. The focus of tuberculosis is thus abolished and the opposite kidney is relieved of a source of irritation which later may produce grave symptoms during the course of the pregnancy and puerperium. Of importance also is the probability that the intensity of the vesical symptoms characteristic of tuberculosis is at times capable of inducing premature uterine contractions. These facts should be given more consideration than the argument that all of the work is thrown on the remaining kidney if one is removed.

A review follows of 35 reported cases of nephrectomy during pregnancy for pathological conditions other than tuberculosis.

Of the 34 patients in whom the result of operation was mentioned, 2 died and 1 suffered from a slight attack of uræmia. The month of pregnancy in which operation was performed was stated in 30 cases as follows: 4 in the second month, 7 in the third month, 6 in the fourth month, 7 in the fifth month, 2 in the sixth month, 2 in the seventh month, 1 in the eighth month, and 1 in the ninth month. The effect on pregnancy was mentioned in 26 cases. Of these the pregnancy continued to term in 17, labor was induced in 2, abortion occurred in 6, and the fetus as well as the mother died in 1 case. The child was normal in all of the 17 cases continuing to term.

A rather extensive search of the literature revealed but 16 cases, in addition to our own 2 cases of tuberculosis of the kidney complicating pregnancy.

Case 1. Reported by Israel. Surg. Clin. for Renal Diseases, viii, 220. The patient, aged 20, was in the fourth month of pregnancy. Recovery of the mother and delivery of a normal child at term followed nephrectomy. Several normal accouchements followed.

Case 2. Reported by Israel. Surg. Clin. for Renal Diseases, viii, 237. The patient was 23 years of age. The month of pregnancy was not stated. Recovery of the mother followed nephrectomy. The effect on pregnancy was not stated.

Case 3. Reported by Doebl. Inaug. Diss., Kiel, 1915. Abstracted by Jaeger in Zentralbl. f. Gynaek. The patient, age and month of pregnancy not stated; recovered following nephrectomy. Spontaneous abortion followed the operation.

Case 4. Reported by Hornstein. Ztschr. f. gynaek. Urol., Leipz., 1909, 1910, ii, 220–233. The patient, aged 22, was in the sixth month of pregnancy. Recovery of the mother followed nephrectomy. Abortion occurred 19 days afterward, the child living 10 minutes.

Case 5. Reported by Mirabeau. Monatschr. f. Geburtsh. u. Gynaek., 1906, xxiii, 197–207. The patient, age not stated, was in the fifth month of pregnancy. Recovery of the mother and delivery of a normal child at term followed nephrectomy.

Case 6. Reported by Pillet (of Rouen) and Delaforge. Ass. franc., d'urol. Proc.-verb., Par. 1910, xiii, 507–511. The patient, aged 23, was in the sixth month of pregnancy. Recovery of the mother and delivery of a normal child at term followed nephrectomy.

Case 7. Reported by Petrard (of Boulogne). Abstracted by Pillet. Ass. franc., d'urol. Proc.-verb., Par., 1910, xiii, 507–511. The patient, aged 34, was in the third month of pregnancy when the infection was discovered. No operation was performed and the patient died in the eighth month of pregnancy.

Case 8. Reported by Pilz. Abstracted by Pillet. Ass. franc., d'urol. Proc.-verb., Par., 1910, xiii, 507–511. The patient, age not stated, was in the fourth month of pregnancy. Recovery of the mother and delivery of a normal child at term followed nephrectomy.

Case 9. Reported by Nicolich (of Trieste). Abstracted by Pillet. Ass. franc., d'urol. Proc.-verb., Par., 1910, xiii, 507–511. The patient, aged 30, was in the third month of pregnancy. Recovery of the mother and delivery of a normal child at term followed nephrectomy.

Case 10. Reported by Boeckel. Ann. de gynéc. et d'obst., Par., 1913, 2 s., x, 145–151. The patient, age not stated, was in the third month of pregnancy. Recovery of the mother followed nephrectomy. A dead child was delivered at 7 months. The cause of death of the fetus was not attributable to the nephrectomy.

Case 11. Reported by Boeckel. Ann. de gynéc. et d'obst., Par., 1913, 2. s. x, 145–151. The patient, age not stated, aborted in the second month of pregnancy. No operation had been performed.

CASE 12. Reported by Koenig. Abstracted by Steinheil, Deutsche med. Wchnschr., 1901, xxvii, 821. Tuberculosis of the kidney was discovered in a patient, aged 25, during the second month of pregnancy. She was delivered at term of a normal child. One kidney had been removed 7 years before because of renal tuberculosis.

CASE 13. Reported by Voron and Bouvier. Bull. Soc. d'obst. et de gynéc. de Par., 1922, xi, 247–248. The patient, age not stated, aborted in the sixth month of pregnancy. No operation had been performed. The patient died 1 week after abortion.

CASE 14. Reported by Schmidt. Surg., Gynec. & Obst., 1915, xxi, 679–684. The patient, aged 28, was in the fifth month of pregnancy. Recovery of the mother and delivery of the child at term followed nephrectomy. The child died 12 days later of sepsis.

CASE 15. Reported by Hartman (Pillet). Trav. chir. 4 s., 1913, 455. The patient, aged 23, was in the sixth month of pregnancy. Recovery of the mother and delivery of a normal child at term followed nephrectomy.

CASE 16. Reported by Seitz. Abstracted by Hussy. Schweiz. med. Wchnschr., 1921, li, ii, 845; 874; 899. The patient, age not stated, made a good recovery after delivery. No operation was performed in this case.

CASE 17. Reported by Stevens. The patient, aged 22, was in the fifth month of pregnancy when the infection was discovered. No operation was performed. The mother recovered following delivery of the child at term. The child, following high forceps delivery, had a tuberculous wound of the neck from which tubercle bacilli were recovered. It died 8 months later of tuberculous meningitis.

CASE 18. Reported by Stevens. The patient, aged 30, was in the second month of pregnancy. Recovery of the mother followed nephrectomy. Abortion occurred 2 months later.

Summarizing the cases of 12 patients nephrectomized for renal tuberculosis during pregnancy the results were as follows: All of the nephrectomized mothers recovered. Normal children were delivered at term in 6 of the cases in which the effect on the pregnancy was mentioned. Abortion occurred in 3 but not until 2 months after operation in 1 of them. The possibility of self-induced abortion must be considered in this case. Another patient was delivered of a dead child at 7 months but this was 4½ months after nephrectomy and death was not due to the operation. The month of pregnancy in which the tuberculous kidney was removed was mentioned in 10 cases and was as follows: 1 in the second month, 2 in the third month, 2 in the fourth month, 2 in the fifth month, and 3 in the sixth month. The result of pregnancy on the renal tuberculosis is stated in 5 non-operated cases. Exacerbation of the condition occurred in 3, death resulted in the eighth month in 1. No noticeable change was apparent in 1. Paul Huessy states that Wildbolz, Kapsammer and Zangemeister each report a case in which tuberculosis of the kidney was apparently but slightly influenced by pregnancy. The result of the tuberculous infection on the course of pregnancy and on the child in 4 cases not operated upon was as follows: Abortion occurred in 2 instances; 1 child was infected at birth and subsequently died of tuberculosis; 1 normal child was delivered at term.

A study of these statistics demonstrates the advantage to both mother and child of immediate nephrectomy in the presence of unilateral renal tuberculosis complicating pregnancy. In this connection the hypersensibility to infection of the offspring of tuberculous parents should also be considered. Norris found that there was an average infant mortality of 58.83 per cent of children born of tuberculous mothers. If our first patient had been nephrectomized at the time the renal tuberculosis was discovered the child would probably have escaped the subsequent infection.

From the above series of cases the conclusion may be drawn that pregnant women stand nephrectomy well and that this operation for renal tuberculosis is no more serious for mother and child than nephrectomy because of other pathological conditions of the kidney during pregnancy. Following the removal of a tuberculous kidney tuberculin should be administered, the urine examined at frequent intervals for a considerable period of time, and the patient kept under observation. Pregnancy is permissible if the remaining organ is free from tuberculosis and functioning normally after a period of 2 or 3 years.

In 261 cases recorded in the literature, together with 4 of his own cases of pregnancy occurring in nephrectomized women, Matthews found that there were 250 normal and 15 complicated labors with but 2 deaths.

In the presence of bilateral involvement properly administered tuberculin treatment,

together with general hygienic measures are indicated. Regardless of the moral or religious aspects of the question I do not believe that sacrificing the child by terminating pregnancy is justifiable as at best the mother's life is prolonged but a short time by this procedure.

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THE CLOSURE OF LARGE FEMORAL AND INGUINOFEMORAL DEFECTS

The Result of Destruction or Relaxation of Poupart's Ligament[1]

By EDMUND ANDREWS, M.D., F.A.C.S., Chicago

POUPART'S ligament is a foundation upon which the whole strength of the anterior abdominal wall rests. In view of its evident importance, it is strange that studies on its development are few and quite contradictory.

Phylogenetically, the picture seems very clear. The continuous fascial plane, made up of the external oblique aponeurosis and the fascia lata, becomes fastened to the anterior superior spine of the ilium and the pubic spine. In all mammals except the primates the thigh has a short range of motion in an acutely flexed position. This sharp folding of the fascial planes would seem to be all that exists in the way of a ligament. The very fact of hyperflexion precludes the possibility of any herniation of abdominal viscera into the thigh. This fascial plane is in reality a degenerated muscle. In man, a rather variable upper part persists as muscle. In dogs, the variation is much more marked; often the entire fascia lata is represented by a thin plate of muscle. In the larger mammals fascia tends to predominate.

Contrast the above with what little we can glean from human embryology. The pelvic girdle in its simplest terms is a straight bar of mesoblastic tissue. The cephalic end represents the ilium, and the caudal end the pubis and ischium. These latter remain fused in primitive forms. This bar rotates so that its iliac end gains a vertebral attachment, while the other end becomes forked, making a notch for the obturator nerve. These pubic and ischial elements later rejoin to make the obturator foramen, and finally fuse in the mid-line, and the symphysis pubis is formed. Even before this stage, however, a splitting off of the anterior iliopubic border occurs to enclose a femoral canal. This can be seen in an 18.5-millimeter embryo (Fig. 1, taken from Keibel and Mall's *Human Embryology*). Thus Poupart's ligament can be distinguished long anterior to any muscle or fascial differentiation.

This latter fact is more in accord with anatomical findings. It has often been stated that the ligament is really only a fold and can be excised and laid out flat, that is, unfolded. This I am able to state is positively not true. Not only in man but also in dogs and cats such excised strips show a definite well-developed ligament which cannot be unfolded.

CAUSES OF DESTRUCTION OF THE LIGAMENT

Destruction of Poupart's ligament may occur from a number of different causes. Partial destruction produces almost as complete a suspension of its function as complete destruction, as the relaxation that ensues completely ruins it as a weight-bearing structure. Its congenital absence has never been reported. The causes of destruction are the following:

1. *Trauma.* The ligament may be injured by penetrating or lacerated wounds. Simple section of the tight band will be followed by wide retraction of the ends.

2. *Infection* may be the result of abscess of the glands in the groin, psoas, or even appendiceal abscess.

3. *Surgery.* (a) In the absence of hernia. In extensive block dissections of inguinal and iliac glands in malignancy.

(b) Willful section, in operations for femoral hernia, in order to permit reduction. Gimbernat's ligament is usually sacrificed first in such cases, but this may not be sufficient and the ring may have to be enlarged in an anterior direction as well.

(c) By too tight stitching or infection in operation for either inguinal or femoral hernia. I have seen this occur after attempts to bring the rectus muscle over too forcibly in a direct hernia, and Twyman (12) suggests that such

[1] Read before the Chicago Surgical Society, March 7, 1924.

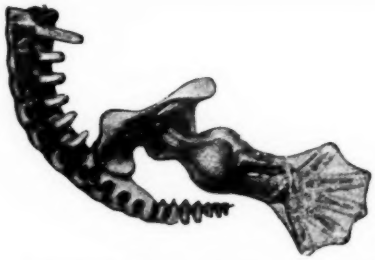

Fig. 1. An 18.5-millimeter embryo showing very early differentiation of Poupart's ligament.

procedures as the Roux operation for femoral hernia may cause it. This consists in forcibly approximating the ligament to the bone beneath it with iron staples.

I want here to call attention to the fact that in the absence of hernia, loss of the inguinal ligament is a far less serious lesion. The real protection against hernia, the endoabdominal fascia, is intact and not stretched or perforated and there is far less danger of hernia formation. Bloodgood (3) reports success in using the pectineus muscle to replace a Poupart's ligament which he removed surgically during a block dissection of malignant glands. He suggested its use in hernia as well, but did not try it. From my observations, such a flabby structure would be of very little value in cases of real hernia where extreme pressure must be combated, although Twyman (12) reports its use in one case as a reinforcing pad over his line of stitches.

Fig. 2. Loosening sheath of sartorius muscle. This is left attached at the upper end to the anterior superior spine of the ilium. The free end is sewed to the pubic spine.

Fig. 3. The same procedure as in Figure 2. The ligament was twisted to gain tension.

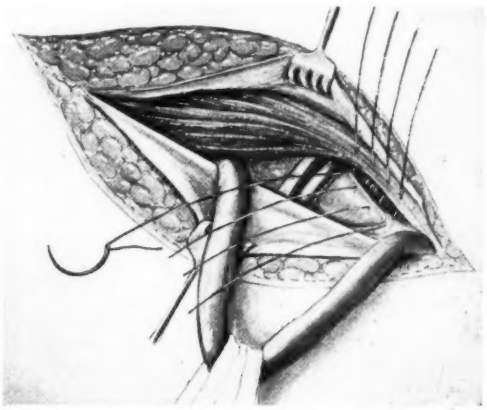

Fig. 4. From Stettin. Suture of conjoined tendon to Cooper's ligament, inguinal route.

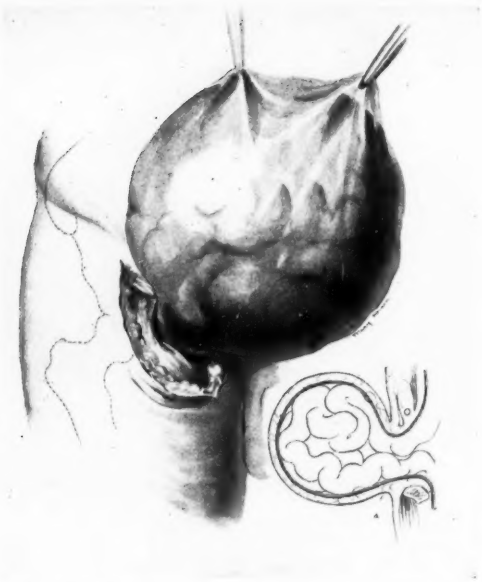

Fig. 5. Sac of enormous femoral hernia dissected free.

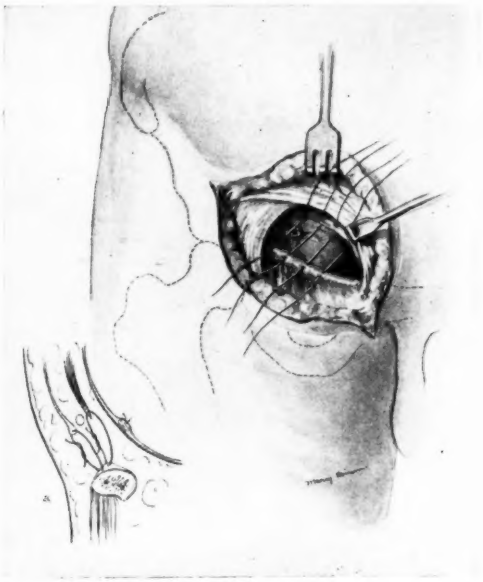

Fig. 6. Access to conjoined tendon from Scarpa's triangle by retracting lax Poupart's ligament. Suture of conjoined tendon to bone.

However, only the real herniæ will be dealt with in this paper.

Allow me to make it very clear that the class of procedures dealt with are not applicable to all herniæ. In most femoral herniæ, which tend to be very small, I believe that very little surgery is needed. Simple removal of the sac followed by skin closure is ample in most cases. This procedure has demonstrated its worth in Ochsner's hands (8), and has lately been ably defended by Russell (10). At the most, one or two simple stitches in the borders of the ring may be needed. It is only for the unusual cases that the measures below described are warranted.

CLASS I. PLASTIC METHODS

CASE 1. A young man with small oblique right inguinal hernia was operated upon three times in 11 months. In two of the operations infection resulted; one was clean. Each time the hernia recurred larger than before. No Poupart's ligament was found at operation. A free strip of fascia lata was sewed into the place of Poupart's. The wound healed by first intention. Total failure was due to general relaxation. The case was deemed inoperable.

CASE 2. A man, age 47, had an enormous hernia for 20 years. An unsuccessful operation had been performed 18 years ago. The fascia of the upper third of the sartorius was stripped off and swung over and sewed onto the pubic spine. The conjoined tendon and external oblique were sutured to this new ligament. A 50 per cent success resulted in considerable diffuse bulging. Reoperation was advised but refused (Fig. 2).

CASE 3. A young man with large inguinofemoral recurrent hernia was operated upon as in Case 2, except that the strip of fascia was twisted in the hope of gaining tension. The result was much better but far from perfect. Three months later, a small incision was made over the new ligament and a figure-of-8 stitch made to tighten it (Fig. 3). The result was good but I have heard since that there is considerable bulging over the old scar.

I am inclined to believe that these plastic operations are of little avail and that the end-result will always be a gradual stretching of any new ligament that we can construct.

CLASS II. SUTURE OF THE CONJOINED TENDON TO THE PUBIS

Wise (13) had the germ of this idea when he suggested carrying the regular Bassini stitch very deep on through Poupart's ligament so

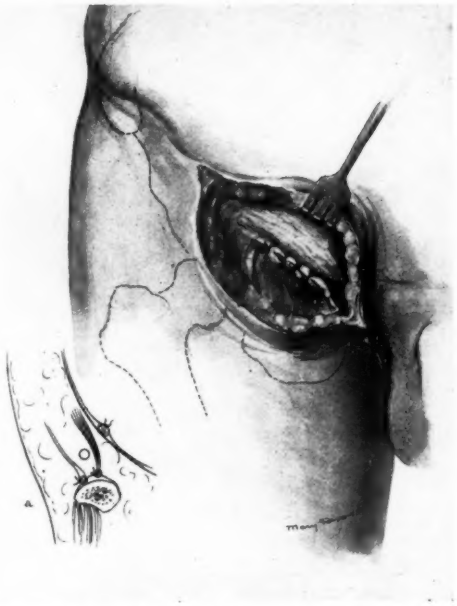

Fig. 7. Suture of relaxed Poupart's ligament to pectineus fascia.

as to include a bit of the pectineus fascia. Groves (4) advocated deliberate section of Poupart's ligament so as to gain access to the conjoined tendon from the femoral canal. He then sutured it to the periosteum of the pubis. I do not regard such a procedure in any way warranted, as all our efforts should be directed toward the preservation of this all important structure. Stettin (11) used the inguinal method of approach (Fig. 4). This procedure has most obvious advantages in this type of work as it bridges across beneath Poupart's ligament and most effectually replaces it. It seems to me that where such a radical procedure is really needed, the femoral route is the better. If Poupart's ligament is intact, such a radical procedure is unnecessary. If Poupart's ligament is very lax, we can gain access to the conjoined tendon beneath it. I have accomplished this in 2 cases.

CASE 1. A woman of 37 with strangulated femoral hernia was operated upon one year before. Prompt recurrence followed. An incision over the tumor showed that the previous operator had not only completely sectioned Poupart's ligament, but had also cut the external oblique aponeurosis for about ½ inch. Attempts to suture the defect proved futile, as the stitches pulled through the parallel fibres. The ligament was then retracted upward and the conjoined tendon (a very strong one) secured beneath it. This was easily pulled down and sutured with 2 kangaroo tendon stitches to the dense fibrous tissue over the ileopectineal line of the pubis (Cooper's ligament). No attempt was made to repair Poupart's. The result was perfect.

Fig. 8. From Bile. Flap of external oblique turned outward as cover for femoral canal.

CASE 2. A hunchback, man, age 54 with marked scoliosis had an enormous hernia the size of an adult head. This was diagnosed a direct inguinal. At operation, it proved to be a femoral with a markedly stretched and relaxed Poupart's ligament. The same operation was done with the addition of suturing the relaxed ligament to the fascia lata. The result was perfect (Figs. 5, 6, and 7).

In both of these cases, the technical difficulties were very slight, and the results appeared far stronger than by any other method known to me. The canal is stopped at its upper end. No pocket is left, and a firm buttress is built even above the abdominal end of the canal. Stettin's method of approach is open to the objection of greater operative difficulty. In spite of the recent flood of literature on the subject, I am far from convinced of the advisability of adopting the inguinal route as a routine. Each time I have tried it, I have got through with the feel-

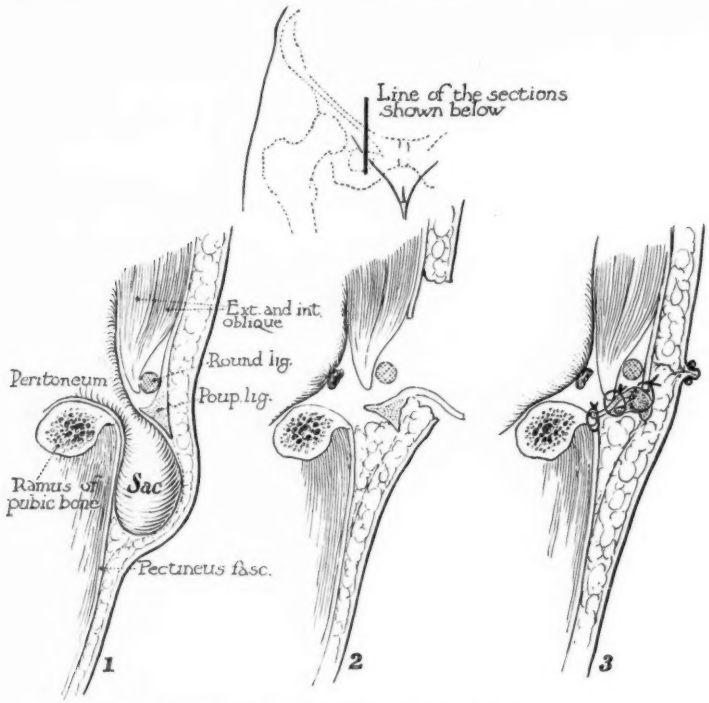

Fig. 9. *1.* Cross section of femoral hernia. *2.* Inguinal incision, and excision of femoral sac through inguinal canal. *3.* Lower fragment of external oblique aponeurosis turned into canal and sutured to Cooper's ligament. Closure of inguinal canal.

ing that I have done an unnecessarily big operation. Aside from such considerations, it is evident that in the class of cases being considered here, the operation can be done far more easily from below.

CLASS III. AUTHOR'S METHOD

Suture of turned-in flap of external oblique aponeurosis to Cooper's ligament.

The great objection to the above method (Class II) is that in most cases where it is indicated it is utterly impossible. The reason is that the conjoined tendon is often congenitally deficient or its lower fibers have been destroyed by too tight stitching. A loose flabby mass of red muscle is of no use, especially if instead of being inserted into the pubis, it is attached to the lateral border of the rectus sheath ¾ centimeter higher up (Polya, 9). In such cases, the operation previously described by me (1) has been used successfully. If the aponeurosis of the external oblique is intact, it can always be done. The only previous mention of the use of this structure in the cure of femoral hernia is by Bile (2). He turned a flap outward and sewed it to the pectineus fascia, thus closing the canal at its lower end (Fig. 8). It was successful in 2 cases of small femoral hernia. As can be seen, the hole left is rather awkward to close.

In the technique I use, the inguinal canal is opened and the upper end of the femoral ring cleared and the sac dealt with according to the usual method variously ascribed to Moschcowitz (7) or Lotheissen (6). The next step is the turning in of the lower flap of the external oblique aponeurosis and suturing it to Cooper's ligament or the periosteum of the pubis. The external and internal obliques are

then drawn and sutured to the remains of Poupart's through the lower turned-in fragment of the external oblique (Fig. 9). We thus have a closure of the canal at its upper end by a strong fibrous membrane which can be laid in without the slightest tension. I do not believe the inguinal canal is appreciably weakened, and no bulging has been noted in any of the 9 cases in which the operation was done by this method (4 operations by the author, 5 by Dr. E. W. Andrews). Three of these were on very large herniæ.

CONCLUSION

1. In ordinary femoral hernia, simple removal of the sac with a minimum of stitching is all that is needed.

2. In large inguinofemoral herniæ, plastic methods are not satisfactory, and should be used only as a last resort.

3. If the conjoined tendon is well developed, its suture to the pubis offers the best chance of cure.

4. In the absence of a strong conjoined tendon, the canal is best closed with the turned-in fragment of the external oblique aponeurosis.

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THE TREATMENT OF STAPHYLOCOCCUS AND STREPTOCOCCUS MENINGITIS BY CONTINUOUS DRAINAGE OF THE CISTERNA MAGNA

By WALTER E. DANDY, M.D., Baltimore, Maryland
From the Department of Surgery, the Johns Hopkins Hospital and University

THE operative treatment of so-called septic meningitis—that in which streptococcus, staphylococcus aureus and albus, pneumococcus, influenza bacillus, and other rarer organisms are the infecting agents—has gained little favor with the passing years. Periodically new operations have been suggested and quickly passed from view; ofttimes the same procedures have reappeared as seemingly new conceptions only to meet a fate similar to that of their earlier entries. Nor have the results been sufficiently noteworthy to maintain the enthusiasm even of the original promoters. Despite the fact that the operative possibilities almost seem to have been exhausted, no impression has been made upon the terrific mortality of this disease.

Surgical efforts toward the treatment of meningeal infections had their crude beginnings even as far back as the time of Percivall Pott (33), in 1760. A century before the bacterial origin of infection was known, we find in his writings a remarkable exposition of the clinical picture of meningitis, which he recognized as a putrefaction of the membranes; and he evidently made a most enthusiastic and persistent effort to prevent and cure meningeal infections by surgical measures. Needless to say, in those days when confidence was placed in phlebotomy, purging, and other vagaries, the radical surgical teachings of Percivall Pott would receive scant recognition; and it is just as well, for despite his superior insight into this disease and his surgical confidence, he far overstepped the mark in treatment. There were so many additional factors—surgical, pathological, and bacteriological—which he could not know and which only now, a century and a half later, are appearing in the light. His reasoning was excellent but his premises defective; yet the surprising thing is how much he knew. The following excerpt from his publication on the results of fracture of the skull might almost be from a modern publication: "And putrefaction of that membrane, tho' least taken notice of by modern writers, is a more frequent cause of bad symptoms, and of death, than all the others put together." Almost equally modern are his impressions on the results of the treatment: "The very terrible symptoms which sometimes follow very slight blows on the head, and the little power of art in many cases to resist, or to remove them, contribute to make this a very melancholy part of practice, and to render the smallest acquisition of knowledge worth all our trouble."

His efforts at treatment were all directed toward the seat of the fracture from which the "putrefaction" was known to have originated. And so great was his fear of the impending danger of involvement of the brain and meninges, that he urged the routine operative exposure and drainage of all fracture wounds, even fissures, as a preventative procedure. A century later Gross (20), in 1873, after experiences in the American Civil War, was still strongly urging the teachings of Pott: "The treatment of compression of the brain from effusion of pus is purely surgical; and all authors are unanimous in the opinion that unless the matter can be evacuated, the patient will die, although they are equally agreed that this measure holds out little chance of life. . . . No case is recorded of recovery from effusion of pus into the arachnoid cavity without its having been let out; on the other hand, if a free incision be made into the dura mater so as to admit of its ready escape, one-half of the patients, as I have just shown, fight their way through. The necessity of operation is, therefore, not to be questioned." The cases cited by Gross, however, are of abscesses or localized cerebral infections beneath fractures of the skull. The

treatment of meningitis as a distinct clinical entity probably begins with the great Victor Horsley (22) in 1890. He applied the principle of drainage (long since secure for many infections) to the cerebrospinal spaces. In addition, he introduced irrigations of the spinal subarachnoid space with mild antiseptic solution. Horsley's treatment in one case was continuous drainage of the spinal canal after laminectomy, and in another irrigation of the spinal canal from the lumbar region to the cisterna magna with his favorite antiseptic—bichloride of mercury. His principle of treatment and results are expressed in the following quotation: "I put down septic meningitis as a condition which might be improved by operation, such as free drainage and irrigation with warm disinfectants. I do not, however, believe that this course will always successfully rescue these otherwise hopeless cases. In fact, I have operated, but both the moribund patients succumbed after temporary but marked remission of their symptoms." Twenty years later, before a German neurological congress (23) in 1910 he still advocated the same treatment, but in the brief note at that time there is no mention of successful results during the long interval after his first announcement.

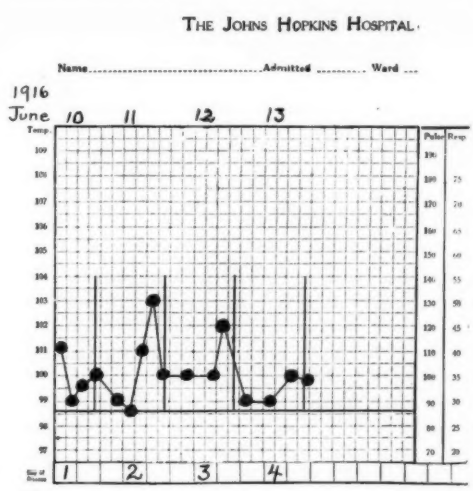

Fig. 1. Temperature chart of a patient with staphylococcus aureus meningitis with spontaneous recovery, showing how mild the course may be.

Since Horsley's unsuccessful effort, three types of treatment have been tried: (1) repeated lumbar punctures (intermittent drainage); (2) continuous drainage from (a) the spinal canal, (b) the cisterna magna, (c) the pontine cisterna, (d) the lateral ventricles, (e) the subarachnoid space in the parietal region; and (3) irrigations of the subarachnoid

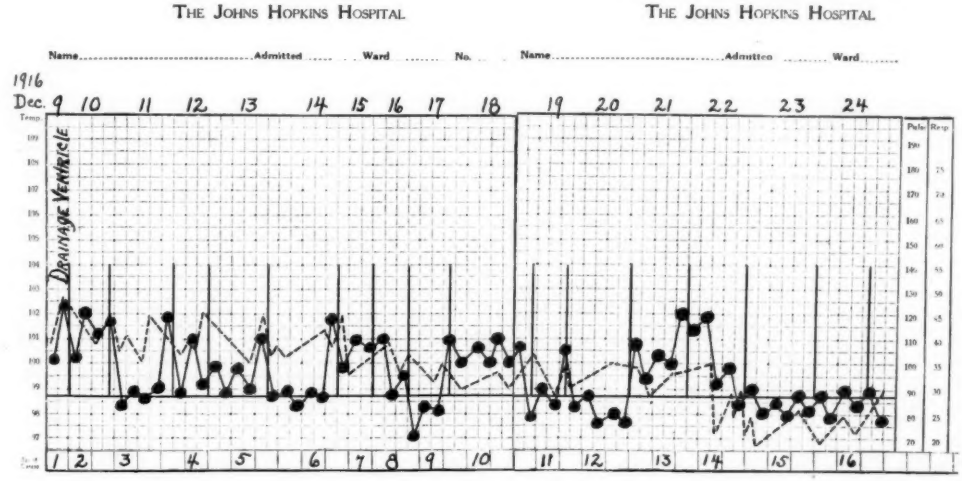
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Fig. 2. Temperature chart showing course following ventricular drainage in case of staphylococcus aureus meningitis following post-traumatic fungus of right occipital lobe.

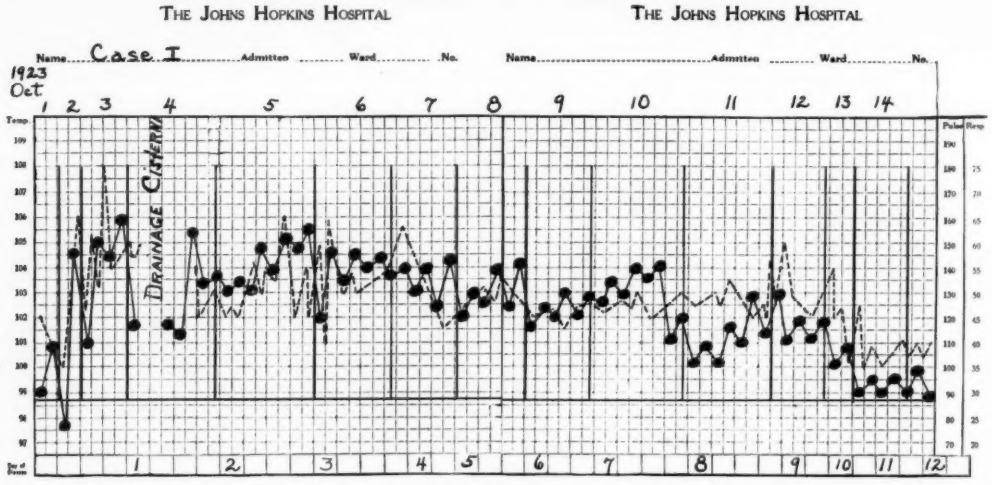
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Fig. 3. Temperature chart to show course following cisternal drainage in patient with staphylococcus aureus meningitis following fracture of the skull (Case 1).

space by bland or antiseptic solutions. As mentioned before, none of these methods has demonstrated any outstanding superiority over the results when the case is left to nature. With very few exceptions each report carries only one or two cures.

There is a very general impression that all forms of septic meningitis are almost universally fatal. If this were true, the reported cures, even though scattered, might be considered the result of the procedure advanced. But, although the mortality is extremely high, spontaneous cures do occur,[1] a fact which makes it open to doubt whether many recoveries—including my own—have really not occurred in spite of, rather than because of, treatment. Indeed, some forms of therapy are so vigorous and many so devoid of surgical and physiological reasoning, that one is forced to the conviction that actual damage has been added to very sensitive tissues which need all their strength to combat the infection.

[1] I have seen one case of staphylococcus aureus meningitis (proven by culture) in which recovery was spontaneous. The symptoms of meningitis developed suddenly 2 months after a radical mastoid operation without pus in the mastoid wound. The temperature, never over 103 degrees, returned to normal in 6 days. The pulse was never over 110; leucocytes, 16,000. This case shows how mild a course of staphylococcus meningitis may be. Nevertheless, the headache was most severe, far greater than in the more serious cases which were treated by cisternal drainage (Fig. 1).

LUMBAR PUNCTURES AS TREATMENT

Surely periodical withdrawal of infected cerebrospinal fluid by occasional, even frequent lumbar punctures, cannot have more than a minimal and transient beneficial effect in the acute phase of meningitis. This impression is based not only upon observations of punctures in meningitis, but upon analogy with aspirations of empyema or other localized infections elsewhere. In the more chronic phase in which pressure is the conspicuous feature of the symptoms, it is probable that sufficient benefit may be obtained to tide the patient over for a definite period. I have repeatedly seen distinct benefit following each puncture in a case which developed from an operative infection, though it was employed only after continuous drainage had been discontinued. Several cures of acute septic meningitis have been reported, among which may be mentioned cases by Kuemmell (25) in 1905, Netter (31) in 1909, and Tedesco (42) in 1910. In pneumococcus meningitis, Lamar (26) collected 13 cures, in 10 of which only lumbar punctures were used. Royster (37) added two more. One cannot but believe that these cases might have recovered if left alone. This feeling is intensified by the fact that only a few punctures were made.

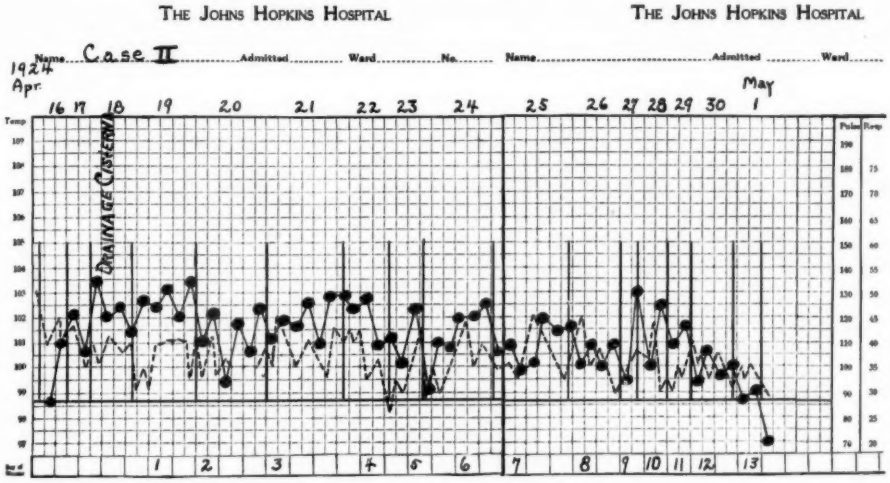

Fig. 4. Temperature chart of Case 2, staphylococcus aureus meningitis, showing course of temperature and pulse following drainage of the cisterna magna.

MECHANICAL IRRIGATIONS

Horsley's irrigation of the spinal subarachnoid space with weak bichloride, and his failure in a single moribund case, has been mentioned. Barr (3) in 1910 irrigated from the sylvian region to the cisterna magna without result. Day (11) in 1913 washed from the ventricles to the lumbar region, and Murphy (29) in 1907 from the lumbar region to the cisterna, both using saline solution without results.

Eagleton (14) in 1921 has adopted a much more radical form of irrigation of the meninges with Ringer's solution. He apparently makes multiple openings over the cortex and irrigates in retrograde fashion into the cisterna magna. His initial report of one cure in 3 cases carries little support for a procedure of such magnitude. In view of the harmful effects from irrigation of the peritoneal cavity and of the failure to benefit deep tissue wounds or infected pleural cavities, irrigations of the subarachnoid space are at once met with a strong feeling of skepticism, particularly when not used in conjunction with continuous drainage. However, since Weed and Wegeforth (43) have shown that irrigations of the subarachnoid space with a modified Ringer's solution is, so far as they can observe in experimental meningitis, without harmful effect, possibilities from the use of this method must still be entertained. It was their feeling that life could be prolonged by irrigating the spinal canal with Ringer's solution, but none of their animals survived. They consider their results suggestive but not conclusive. Exponents of irrigation methods realize that because of free communication through the foramina of Luschka and Magendie, the ventricles and the entire subarachnoid space are always infected and that the topography of the cerebrospinal space is such as to make irrigation of more than a fraction of the entire system impossible, regardless of the sites of punctures. Any possible results, therefore, are to be expected solely from a quantitative reduction in the number of infecting organisms. One cannot escape a fear that even Ringer's solution may at times not be so perfectly balanced as to prevent harm to the tissues; and even though the injury is not enough to give evidence to our crude tests, it may yet be sufficient to favor the growth of organisms. Even though it is granted that a harmful effect is lacking, beneficial results could hardly be expected to accrue unless irrigations were continued at frequent intervals.

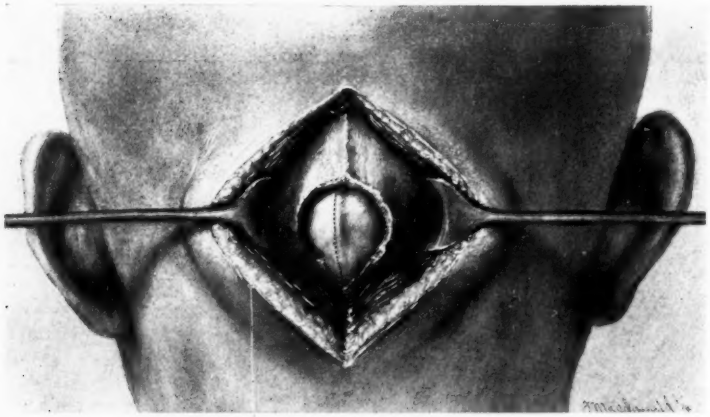

Fig. 5. Operative exposure for drainage of the cisterna magna.

ANTISEPTIC INJECTIONS OR IRRIGATIONS

Attempts to cure meningitis with antiseptic injections or irrigations have doubtless caused injurious rather than beneficial effects. The outstanding claims for chemical treatment are those of Franca (17) in 1903 and (18) 1917, his coworker Seager (39) in 1902 with lysol, and Wolff (46) in 1915 with protargol; but all were dealing with meningococcus meningitis in which Flexner's serum has since completely revolutionized the treatment. The remarkable percentage of cures by lysol and protargol—equal to those of Flexner's serum—have not been duplicated by others. Recently their claims were carefully examined by Flexner and Amoss (16) with entirely opposite results. They tested the bactericidal power of the given strength of lysol and protargol, both *in vivo* and *in vitro*, and found them to be without any effect. Their conclusions were that "the chemicals have shown themselves not to be curative but rather to be injurious. . . . The chemicals have been shown to be antileukotactic, antiphagocytic and, indeed, to be all poisons of considerable power."

Franca also claimed that the bactericidal action of lysol was equally strong for streptococcus and other organisms except pneumococcus, but proof of this statement was not given.

From the remarkable series of observations by Weed, Wegeforth, Ayer, and Felton (44) of the American Army Neurosurgical Commission, those facts pertaining to chemical irrigations are particularly impressive. Weed and Wegeforth (43) showed that the chemical irritation even of normal salt solution is so great that following irrigations of the spinal canal in their meningitic cats, there were convulsions, marked tetany-like shaking of the body, retraction of the head and neck, great general irritability on recovering from the anæsthetic, and in a very high percentage of cases death quickly followed from respiratory paralysis. That the meninges are extremely sensitive to chemicals, we (9 and 10) have learned in the use of the phenolsulphonephthalein test for absorption of cerebrospinal fluid. If this dye was either slightly acid or alkaline, the results in animals were precisely similar to those of Weed and Wegeforth. It is for this reason that great emphasis has always been placed upon the use of a perfectly neutral solution.

In another series of animals with experimental meningitis, Wegeforth and Essick (45) irrigated the spinal canal with many of the commonly used antiseptics and found that none prolonged life. With sublethal doses a violent reaction occurs, manifested by an extreme increase in the globulin content and cell count. The evidence is surely adequate to eliminate from consideration the treatment of purulent meningitis by irrigation of the subarachnoid space by any of the

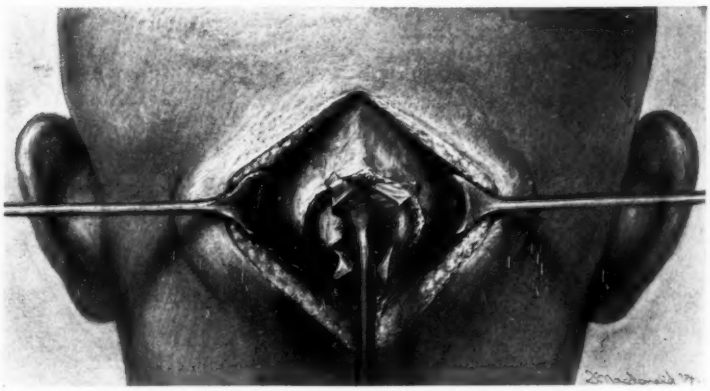

Fig. 6. Showing funnel end of tube sutured to dura on each side. The tube remains flush with the dura and does not project into the cisterna. The dural defect is purposely made larger than the end of the drainage tube and one or two openings are made into the tube as an additional safeguard against closure of the mouth of the tube.

antiseptics which have heretofore been used. This is by no means an effort to close the door to future efforts in this direction. Despite past and present failures, one cannot but feel that the future treatment of septic meningitis may yet lie in antiseptics or sera. Though seemingly impossible from our present knowledge, the detection of a specific antiseptic or of a specific serum so accurately balanced as to be without injury to the naked nervous system, seems no more unlikely than Flexner's remarkable antimeningococcic serum, or the recent brilliant discovery by Sicard (40) that lipiodol could be injected into the subarachnoid space, cast a dense shadow, and still be harmless to the delicate host.

RESULTS FROM CONTINUOUS DRAINAGE

The two favorite sites for cerebrospinal drainage are the lumbar spinal canal and the cisterna magna. Continuous drainage of the lateral ventricle is difficult, hardly practical, and except under unusual circumstances,[1] never necessary or advisable. Attempts at ventricular drainage, aside from the fact that they are both unnecessary and impractical, lead to unwarranted damage to the cerebral cortex. Despite their many curves, the ventricles remain open and drain well into the cisterna magna through the foramina of Luschka and Magendie. At least the automatic drainage from the ventricles is much superior to other parts of the subarachnoid space unless, or until, the foramina of Luschka and Magendie become occluded. This is a not infrequent sequel in the later stages in many cases of meningitis and, of course, the resultant hydrocephalus is a very serious complication. This will be alluded to elsewhere.

Soon after Horsley's drainage of the spinal canal (1890), Wynter (47) in 1891 inserted a needle between the vertebræ for drainage, slightly antedating the introduction of Quincke's method of lumbar puncture, and in another case he removed a lamina and drained the spinal fluid. It is claimed that he antedated Horsley also, but Horsley's publication appeared a year earlier. Parkin (32) in 1893 and Ballance (1) in 1897 each reported a drainage of the cisterna magna but without a resultant cure; in 1923 Ballance (2) still advocated the same method, though his results were not mentioned. Haynes (21) in 1912 revived drainage of the cisterna magna, devising an operative procedure much like one earlier advanced by Murphy (29) in

[1] Six years ago I removed a bullet from the occipital lobe of a boy 24 hours after the accident. A cerebral fungus persisted for weeks afterward and gradually the infection reached the lateral ventricle, meningitis developing. Staphylococcus was recovered from the spinal fluid. In this case I drained the ventricle through the old bullet tract. The patient recovered. It is only under conditions of such unusual character that ventricular drainage is justified. Almost the entire drainage tract (as large as the finger) had been made by the course of the bullet and the resulting fungus, from which the infection arose (Fig. 2).

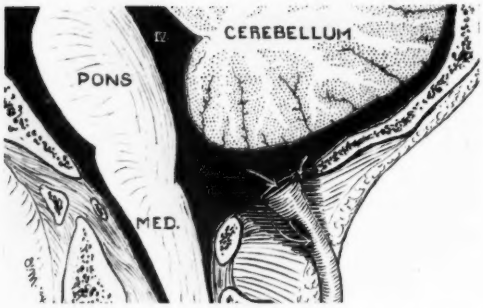

Fig. 7. Diagram showing the position of the tube and its relation to the cisterna magna.

1907. His 3 patients operated upon in the late stage of the disease died without more than transitory benefit. Day (12) in 1913 faithfully tried Haynes' method in 12 cases, only one surviving. Dench (13) in 1913 used the same operation on 3 patients without success.

Probably more cures have been reported following spinal drainage than after any other surgical procedure, possibly excepting lumbar puncture, but the number even of these is quite small. Macewen (28) is often credited with 6 cures in 12 cases of meningitis, but in his cases the meningitis was focal and his operation restricted to the treatment of this focus. However, he looked upon drainage of the meninges through "single or multiple laminectomies with irrigations" as a possible hope "if the pus is still fluid." Rolleston and Allingham (36) in 1899 and Goebell (19) in 1909 each reported 1 cure, and Barth (4) in 1914, 3 cures after spinal drainage. By the same method Leighton and Pringle (27) in 1915 report recovery of 2 cases of streptococcus meningitis following trauma, and 2 additional cases of streptococcal origin have just been reported by Rainey and Alford (35) in 1923.

Attempts have also been made to drain the lateral pockets of the cisterna magna and of the pontine cisterna by a dural defect in the mastoid. Such a fistula must be especially prone to secondary skin infections owing to the absence of soft tissues to protect and close the fistulous opening. Jenkins (24) in 1922 and 1923 admits two mortalities from this cause. Little can be said in favor of drainage from the parietal region, though cures have been reported. It opens only a small isolated area of the subarachnoid space, and on only one side of the brain. Cures have even been reported following decompressions; surely a more irrational program could not be suggested. One must not be misled by the optimistic reports of Jenkins' most radical procedure. He was dealing not with meningitis (for in none of his cases were organisms found in smears or grown on culture media) but with the well recognized sterile meningeal reactions to mastoid infections which will take care of themselves when the primary infection is properly treated.

The above reports at least show a considerable number of cures. Why there should be such a difference in the apparent results between drainage of the cisterna and of the lumbar spinal canal, is difficult to understand. There can hardly be any superiority of spinal over cisternal drainage, if properly done. If results from cisternal drainage do not equal those of lumbar drainage, the conclusion is justified that the principle of drainage itself is useless. That drainage will cure empyema, etc., is not proof that it will cure meningitis. In one case there is a single space, in the other a very complex circulatory system. Even the results of draining empyema depend upon the nature of the infection. For instance, the results in streptococcus empyema, especially in the early stages, are such as to cast doubt upon the efficacy of the method.

The difficulties of judging reports of cures following treatment are: first, that the death rate without intervention cannot be accurately estimated; and, second, that the infecting organisms, though generally grouped together, differ greatly in their virulence (staphylococcus aureus, albus, streptococcus, pneumococcus, influenza bacillus, etc.); also because the pathogenicity of organisms even of the same species is exceedingly variable.

Brun (5) reports an 80 per cent mortality from untreated meningitis following fractures of the skull. This is the lowest mortality rate I have been able to find. Preysing (34) in 1912 thinks there are more spontaneous recoveries from post-traumatic than from

post-otogenous meningitis, an opinion which also seems to be borne out by the fact that most of the cures reported following drainage are from post-traumatic cases. So many different factors are involved in these two general types of infection (traumatic and otogenous) that one can only theorize on their relative importance. The degree of fractures of the skull and the grade of infection in the sinuses at the time of the break in the bone, vary tremendously. A small crack in the floor of the skull, when passing through a nasal sinus or mastoid and quickly closing over, would obviously be a less dangerous portal of entry for organisms than a larger one which must remain patent for a longer time. A fissure in an acutely infected sinus would be far more serious than one through a sinus without signs of infection; and similarly an otogenous infection penetrating the meninges and constantly feeding the cerebrospinal fluid would probably offer more potential danger than a single infecton entering through a defect which closes quickly.

Barr (3) in 1910 was able to collect only 50 cases of purulent meningitis cures following operation, Eagleton (14) in 1921 only 30 cases. Neal (30) in 1914 found only 5 cases of streptococcus meningitis which had recovered. She also makes the statement that when Friedlander's bacillus is the infecting agent there is a much higher tendency to recover. Singer (41) in 1924 reports a spontaneous cure of this rare form of meningitis. Though many cases have been overlooked and many more not reported, these figures at least emphasize the high mortality of the disease. At best, the mortality of all varieties of septic meningitis is excessively high. It will surely run well over 90 per cent and in many forms will probably be over 95 per cent. There is little evidence to support or disprove the general impression that on the whole streptococcus infection is more fatal than staphylococcus, either of the aureus or albus type. All appear about equally fatal. Schlesinger (38) using a serum treatment reports the cure of a case of pneumococcus meningitis.

The virulence of the organism is the most important factor in the differences seen in the clinical course and in the mortality rate. Cases which fulminate are paralleled by those which run a longer and milder course, even though the bacteriological findings are similar in each. There is no better proof of this than the experiments of Felton and Wegeforth (15) who were unable to make any satisfactory observations on any form of treatment of experimental meningitis produced by streptococcus and staphylococcus because "of the characteristic variability in pathogenicity" of those organisms.

EVIDENCE THAT DRAINAGE MAY OR MAY NOT BE EFFECTIVE

A priori, one would reason that septic infections of the meninges should be drained continuously, as infections elsewhere, and if possible treated by appropriate antiseptic solutions, but the topography of the cerebrospinal spaces offers serious difficulties to the former, and the delicacy of the central nervous system has as yet precluded the latter. And differences in the character of the infections themselves have a most important bearing on the success or failure of any form of treatment.

It is unsafe to draw the conclusion that because purulent meningitis is a septic infection, drainage is necessary or even helpful. Analogy with the drainage of other infected cavities is untenable. Not only the character of the infection, but the anatomical features of the serous cavities must determine whether drainage is useful. Drainage of a pleural cavity is simple because this is a single undivided space. Drainage of the peritoneal cavity is impossible because of the many pockets which form between the abdominal viscera and especially the intestinal loops. And from the other angle, drainage of pneumococcus empyema is a necessary life-saving procedure, but drainage of an acute streptococcus empyema is of doubtful value. The efficiency of drainage of any infection from any space is, therefore, an individual determination.

The cerebrospinal fluid circulates in a closed system of spaces. The *interior or ventricular part* of the system is concerned with the *formation* of cerebrospinal fluid; the *exterior or subarachnoid part* with the *absorp-*

tion of the fluid. Communication between the ventricular and subarachnoid divisions of this system is solely through three openings in the 4th ventricle—the paired foramina of Luschka and a mesial foramen of Magendie. Closure of these foramina inevitably leads to dilatation of the four ventricles from the pent-up fluid which can no longer be absorbed (in more than minimal amounts). These openings are, therefore, absolutely necessary to the circulation of cerebrospinal fluid, to the integrity of the brain, and to the life of the individual.

The subarachnoid part of the cerebrospinal system in the shape and distribution of its component parts may roughly be compared to a tree. The large cisternæ underlying the brain-stem, the interpeduncular and interchiasmal regions of the brain, and surrounding the spinal cord and the posterior aspect of the cerebellum, form a single large trunk without restricting anatomical subdivisions. From this trunk many branches radiate over all the cerebral and cerebellar surfaces forming a network of intercommunicating channels and pools. Over the cerebrum these spaces conform more or less to the irregularly distributed interconvolutional spaces (sulci). It is from this point of the subarachnoid space, cerebrospinal fluid is absorbed; and from the standpoint of surgical therapy (drainage or irrigation) this is, doubtless, the weakest link because the channels are so interlaced and the communications so small. Under normal conditions the entire system of cerebrospinal spaces, both ventricular and subarachnoid, are in very free communication. This can be proven in two ways: (1) a cubic centimeter of a harmless dye, such as phenolsulphonephthalein, injected into any part of a lateral ventricle will appear in the spinal fluid in less than 3 minutes and an inverse test (i. e., from the spinal canal to a lateral ventricle) demonstrates that the dye is transmitted with equal rapidity in this direction; (2) if a cubic centimeter of India ink replaces an equal amount of cerebrospinal fluid in the cisterna magna (pressure remaining unchanged), the ink granules will be freely distributed throughout the most distant branches of the subarachnoid space (over the cerebral hemispheres) in less than one hour. Another proof of the very free communication between all the cerebrospinal spaces is the rapidity with which air injected into the spinal canal normally reaches all the cerebral sulci and cerebral ventricles (only a few seconds are required).

These experiments, particularly the latter, are also proof that drainage of the entire cerebrospinal system is possible, under normal conditions at least, either from the cisterna magna or the spinal canal. Under abnormal conditions of infection, however, the possibility of drainage of the entire cerebrospinal system will be dependent upon the changes induced by any particular infection. The reaction of the meninges, as evidenced both by the changes in the cerebrospinal fluid, and in the meninges, and even at times in the cerebral tissues, varies so greatly with different infections that the mechanical factors upon which drainage depends are far from similar. For example, pneumococcus infection quickly produces a very thick, tenacious, fibrinous exudate; this is in marked contrast to the cloudy but still limpid fluid (at least in the earlier stages) of staphylococcus aureus and streptococcus infections. It is hardly possible that a thick purulent exudate could even be drained from the larger cisternæ or the spinal canal, and surely not from the finer radicles of the subarachnoid space—even in the very early stages of the infection. For this reason *I have restricted the application of cisternal drainage to staphylococcus and streptococcus infections in which the cerebrospinal fluid is not sufficiently altered in consistency to militate against drainage.* However, my experience with other infections of the meningeal spaces is not great enough to arbitrarily exclude them all from this form of treatment. There may well be many instances among this great group of infections where the fluid alterations are less intense and where drainage may be practical.

THE OPERATIVE PROCEDURE

As emphasized before, the operative procedure differs only in details from that of Haynes, the principal difference being in the reliance upon tube drainage. Our original

plan was to devise a method free from the danger of a secondary infection. The difficulty—one sometimes thinks almost the impossibility—of maintaining the sterility of cerebrospinal fluid which is pouring over the skin, is well recognized. Only meticulous care can prevent, and then only for a brief period, a secondary infection from the skin organisms, and such secondary invasions are almost surely fatal.

A midline incision is made over the occiput. The nuchal muscles are retracted exposing the occipital bone, the atlas, and the intervening atlanto-occipital membrane (Fig. 5). A circular area of occipital bone (about 2½ centimeters in diameter) is rongeured away, including the posterior arch of the foramen magnum. The exposed dura is then continuous with the occipito-atlantal membrane. The dura is opened at or near the midline and the incision carried upward to the margin of the bony defect and backward to the atlas. The terminus of the occipital sinus, if present, is at first avoided and later ligated with a transfixion suture. One or more lateral dural incisions are then made on each side in order that the opening may be ample and so protect against premature closure of the fistula. The arachnoid covering the cisterna magna is then opened widely, allowing the cerebrospinal fluid to escape. Any slight bleeding from the dura is controlled by transfixion sutures. The only danger of the procedure, *per se*, is postoperative bleeding into the unprotected cisterna magna. A tiny ooze may escape detection or seem insignificant at the operation, but, there being no opposing tissue to act as a hæmostat, and the dura being noncontractile, the bleeding may continue and be very serious. Ballance reports the loss of a case from this cause. The funnel end of a small catheter is sutured to both sides of the open dura with catgut ligatures (Fig. 6). The mouth of the catheter is thus fixed to the dura and flush with it. The tube is made wider than the dural slit at the points of fixation in order to insure against possible intrusion of the tube against the brain. Additional insurance against such a possibility is obtained by suturing the tube to the trapezius muscle with catgut and to the skin with silk.

Dural openings above and below the fixed mouth of the tube are purposely left open as a safety valve for the escape of cerebrospinal fluid if the tube should become clogged. The trapezius muscles are only partially brought together in order that fluid may also collect between them if the tube should not take care of the drainage. A second opening in the side of the tube is intended to afford exit for any such pocket of fluid. And, finally, the skin is only loosely closed around the tube as an additional safety vent for any possible collection of fluid which might form around the tube and not be able to escape through the lateral aperture (Fig. 7).

Drainage through the tube has been remarkably effective; secondary drainage around the tube into the dressing has only occurred once and for a very brief period. On withdrawal of the tube after several days (4 to 7), discharge of fluid into the dressings persists interruptedly for only 1 or 2 days. It is only during this time that we are fearful of a secondary infection. The strong, deep muscles of the neck are the greatest insurance against a continuation of a discharging sinus—a protection which is entirely lacking when lateral drainage of the cisterna is employed. In no instance has there been any noticeable effect from the continuous loss of cerebrospinal fluid.

REPORT OF 4 CASES OF STREPTOCOCCUS AND STAPHYLOCOCCUS MENINGITIS TREATED BY CISTERNAL DRAINAGE: 3 CURES, 1 DEATH

These patients have been treated by continuous drainage of the cisterna magna, the operative procedure differing only in detail from that of Haynes (21). In 1 patient the infection followed a fracture of the skull (streptococcus hæmolyticus); another followed lumbar puncture (staphylococcus aureus). Two were postoperative infections (1 streptococcus hæmolyticus and 1 streptococcus viridans) which developed after removal of cerebellopontine tumors. Three of these 4 patients recovered and 1 (streptococcus hæmolyticus) died. The cases are briefly summarized as follows:

CASE 1. A boy of 6 years was struck by an automobile. He was unconscious on arrival at the hos-

pital, and bled from the nose and left ear. Some cerebrospinal fluid drained from the nose. Within a few hours the patient became quite conscious. The day following the accident his temperature rose to 104.5 degrees F., and the pulse to 160 (Fig. 3). His neck was rigid; Kernig's sign was positive. He was very drowsy but irritable; white blood cells, 27,000. The fluid from lumbar puncture was cloudy; smears showed micrococci which on culture proved to be streptococcus hæmolyticus. On the following day his temperature rose to 106 degrees, pulse to 180, and he became very irrational. Sixty hours after injury, and 36 hours after the first signs of meningitis, the cisterna magna was drained by a small rubber tube (Fig. 3). Fluids were forced by mouth.

The drainage tube was removed on the seventh day, but drainage continued through the tract 2 days longer. No change in his temperature followed immediately, nor for 4 days after drainage was begun. However, his general condition was at once appreciably improved, the principal change being that he was a little more alert and less drowsy. The temperature returned to normal on the eleventh day (9 days after operation). There were slight rises for several days thereafter. The drainage averaged about 100 cubic centimeters per day for the first 3 days, gradually diminishing thereafter. His recovery was then uneventful. Six months later he was perfectly well.

CASE 2. A boy of 11 years developed meningitis following lumbar puncture. Five days later the cerebrospinal fluid was cloudy and contained 1,550 cells per cubic centimeter; staphylococcus aureus grew on culture media. His neck was rigid; there was opisthotonos; he was very drowsy and irritable.

Operation. Continuous drainage of the cisterna magna was begun 5 days after the first sign of meningitis (Fig. 4). Fluids by mouth were forced. The drainage measured 350 cubic centimeters, 225 cubic centimeters, 205 cubic centimeters, on 3 successive days after the operation. The tube was removed after 5 days. Intermittent drainage through the sinus tract persisted 2 days longer. The patient's temperature and general condition did not change immediately or for several days following drainage. The temperature returned to normal 14 days after operation and did not again become elevated. Recovery followed; and 5 months later he had no residual signs or symptoms.

CASE 3. Mrs. K., age 36, 18 hours after the partial removal of a cerebellopontine tumor, was suddenly seized with a severe chill. The temperature quickly rose from the postoperative level of 101 degrees to 105.4, and the pulse from 120 to 170. The cisterna magna was reopened 36 hours after operation and purulent fluid escaped. Streptococcus hæmolyticus grew from the culture. The patient died 24 hours later, or about 60 hours after the operation. It should be noted that the immediate postoperative course was entirely uneventful; she was soon conscious and just before the chill was considered well out of danger. Drainage had no appreciable effect on the temperature or the condition of the patient.

CASE 4. Mrs. W., age 49, was operated upon 24 hours after the preceding patient (Case 3). A typical cerebellopontine tumor was totally extirpated. A streptococcus viridans infection followed. Unlike the preceding case, there was no sudden onset of symptoms of meningitis. Her temperature failed to return to normal and on the eighth day after operation began to rise from a general level of 100 to 101 degrees to a little higher level each succeeding day, reaching 104 degrees on the fifteenth day. Although she was drowsy and at times irrational, her general strength was better than her temperature would indicate. The pulse ranged between 100 and 110.

Ventricular puncture. The fluid was cloudy and contained 1,840 cells; streptococcus viridans grew from the culture. Drainage of the cisterna was withheld until the eighteenth day and was continued for 4 days. Following removal of the tube, fluid was aspirated from the lateral ventricles, the spinal canal, or the cerebellar cistern by punctures once or twice daily. Her temperature remained elevated 43 days after the onset of drainage and 61 days after the operation, very gradually returning to normal. Though there was no immediate temperature response, a decided improvement in her general condition came immediately after drainage was begun; she was at once much less drowsy. In this case the drowsiness was undoubtedly largely a pressure phenomenon. The degree of intracranial pressure could always be easily determined in her case by the fulness and tightness of the cerebellar decompression. The decompression was therefore used as an indicator for the many aspirations which were necessary; and after each of these aspirations a decided improvement in her condition followed. Continuous drainage was stopped earlier than in the other cases because of the fear of a secondary infection through the shallower sinus tract and because tapping was found to satisfactorily control pressure symptoms in this relatively slow chronic type of infection. She has now been perfectly well over 4 months. She has no headaches or other symptoms; the decompression is soft and retracted. About 35 aspirations (from the locations mentioned) were made after cisternal drainage was stopped; gradually the interval between punctures was lengthened until their discontinuance on the seventy-seventh day after operation. The rescue of this patient is due to the ceaseless vigil and unremitting care of my assistant, Dr. Firor.

INTERPRETATION OF RESULTS

Our results are greatly at variance with those of Haynes, Day, Dench, and others who have used much the same method and have found no appreciable reduction in the mortality rate as compared with nature's course. Differences in the operative procedures could

not be responsible. But it would be unfair to draw generalized conclusions without a more careful analysis. Though all cases of meningitis are extremely ill and carry an exceedingly high mortality, the variations in severity are striking. Doubtless their cases were much graver than mine. In all of their patients the meningitis was of otogenous origin and, while statistics are too meagre to draw upon, this form of meningitis (for the moment excluding the kind of organism) is probably more severe than that following trauma or the accidental inoculation of the cerebrospinal fluid. Patients with meningitis of otogenous origin must combat two big infections, one local in the mastoid, the other in the meninges; and the primary infection must appreciably reduce the patient's vitality to combat the secondary meningitis. Moreover, in post-otogenous meningitis there are more intracranial complications, such as cerebral abscess and sinus thrombosis, any of which would make the patient's recovery extremely unlikely regardless of any effective treatment of the meningitis. These operators have also indiscriminately used drainage in all cases of meningitis without considering the type of organism. Thus 4 of their 9 cases were pneumococcus meningitis, a form in which the exudate is so thick and fibrinous that drainage would probably be without any beneficial effect whatever. Our cases have all been accidental infections of the meninges without other complications, except that in 2 cases big intracranial operations for the removal of tumors preceded the infection. All have been streptococcus and staphylococcus infections in which the character of the fluid is such as to make drainage feasible and, in the results, it is to be understood that only these meningeal infections are considered. It may well be open to objection that all of these patients might have made a spontaneous recovery had they been left alone. In favor of such an assumption is the fact that there is no change in temperature or leucocyte count[1] and only a slight change in the general condition of the patient. In 2 patients we felt there was a little less drowsiness and less complaint of headache, though they were probably just as irritable and irrational as before drainage. It is only on the basis of the ultimate results that I am able at all to combat the assumption of possible spontaneous cures. While the statistics of the literature indicate an exceedingly high mortality, probably over 95 per cent, my series is far too small to consider statistically; it is entirely possible we may have had a very fortunate group of cases. Case 4, the long drawn out viridans infection, is an exception to the statement that no great change in the general condition followed. There is no doubt that the patient was maintained in a conscious and semi-conscious state by the withdrawal of fluid, for this pressure phase of the disease could always be directly observed by the size and tension of the decompression. Such a change would be less likely to be appreciated in the more acutely ill patients where pressure manifestations probably play a less conspicuous rôle.

At best it is evident that the procedure does not offer a panacea even for cases of streptococcus and staphylococcus meningitis. The single death is evidence of this. The overwhelming character of this infection is shown by the severe chill and its rapid appearance (18 hours) after the operation. Each case of septic meningitis is a law unto itself, the factors being the kind of organism, the virulence of the organism, the resistance of the patient, the concomitant complications, and also the manner of entrance of the infection.

Granted that drainage of the cerebrospinal system is possible, what will it accomplish? It has been shown from the temperature charts that no temperature reduction follows at once, nor for days afterward; also, that the patient's general condition is not markedly, though probably slightly, improved immediately after drainage. Meningitis produces two kinds of symptoms: those due (1) to toxæmia and (2) to pressure. There can be no doubt that in every case of meningitis both factors play a rôle, though the relative degree of each is variable for different infections and probably also for different stages in the same illness. In all the acute streptococcus aureus and staphylococcus hæmolyticus infections,

[1] In Case 1 the leucocyte count was 27,000 before operation, and varied between 17,000 and 25,000 for the next 7 days, gradually falling with the temperature.

the overwhelming factor is the toxæmia and the smaller but very important factor is pressure. The reason for this conclusion is that the irritability, delirium, fever, leucocytosis, and tachycardia are not influenced by the sudden pressure relief.

It is well recognized that cerebrospinal fluid absorbs very quickly from the subarachnoid space. Over 40 per cent of phenolsulphonephthalein injected into the spinal canal will normally be excreted in 2 hours, and its first appearance in the urine will be in less than 2 minutes (9). To this rapid absorption is due the overwhelming systemic effect of the meningeal infection. And doubtless also much of the defense of the meninges is due to rapid transfer of much of the infection from the subarachnoid space into the venous circulation.

But the actual amount of cerebrospinal fluid and its pressure are markedly increased. In the slower streptococcus viridans infection (Case 4) the pressure element was much greater; in fact, it was without question all-important to the patient's tenure of life. The importance of the element of pressure can also be understood from two recent experimental efforts on 2 comatose patients. In 1 the condition was due to tuberculous meningitis, in the other to a prolonged refractory meningococcus meningitis (eighth week). Each quickly became entirely conscious again, later succumbing to the disease (5 and 12 days respectively). In neither case was the temperature lowered.

Intracranial pressure in meningitis is of twofold origin. In the acute stages of the disease the fluid surely is an overproduction arising from inflammation of the meninges. Later the increased fluid is due also to occlusions which develop in different parts of the subarachnoid space: (1) in the foramina of Luschka and Magendie, (2) in the cisternæ beneath the brain-stem and (3) in the subarachnoid spaces over the cerebral hemispheres. Hydrocephalus inevitably follows any of these occlusions. Roentgenological and pathological proof of these variously situated obstructions have been shown in previous reports by the author (6). In the natural course of events in the process of healing, these obstructions may absorb and lead to spontaneous reopening of the cerebrospinal spaces or cicatrize and lead to chronic progressive hydrocephalus. It often develops in tuberculous meningitis and in other obscure forms. Recently I reported a case in which hydrocephalus followed a meningeal complication of measles (7). But consideration of hydrocephalus following the healing of meningitis is not within the scope of this paper. Doubtless the overwhelming proportion of its incidence is in the wake of meningococcus meningitis. The reason for this statement is that this is the only type of meningitis which heals spontaneously in sufficient numbers to account for this common form of hydrocephalus, and also that we have so frequently observed this complication in meningococcus meningitis. But hydrocephalus is also a problem of acute and subacute meningitis. In the case of meningococcus meningitis mentioned above as treated by cisternal drainage, the foramina of Luschka and Magendie were occluded and a ventricular empyema followed. With such a complication, drainage of the cisterna magna, or of any part of the subarachnoid space can, of course, bring no permanent relief. Nor does it seem probable that any form of surgical treatment will be effective. It is easy enough to reopen a foramen of Magendie, but the persisting infection will almost certainly close the opening again. Drainage of the ventricles from any other point to the exterior is only temporizing, for no cure can result until drainage of the ventricular fluid into the subarachnoid space is established.

Whether hydrocephalus is ever a complication of staphylococcus or streptococcus meningitis, I do not know. I have hoped that if continuous drainage of the cisterna aided in the cure of these forms of meningitis, it might be equally effective in *preventing* this complication. In Case 4 the possibility of obstruction at the base was always feared, but did not develop. In all cases operated upon, we have added a perforation of the skull in the occipital region of each side, so that the lateral ventricles can be tapped at any time. This precaution adds only a few seconds at the time of operation, and makes it possible

to tap a ventricle (as in Case 4) for the temporary relief of pressure, but more important, it allows us to always know at any time if the foraminæ of Luschka and Magendie are patent. Registration of the ventricular pressure alone should give this information, but if any doubt exists the harmless indigocarmin test (8) will eliminate all doubt.

It may be asked wherein lies the advantage of cisternal drainage over lumbar drainage. If continuous drainage could be equally well maintained by lumbar drainage, the effects should be the same. The only superiorities of cisternal drainage should be that continuous drainage is actually easier to maintain, and that the drainage tract is easier to close when desirable. The cerebellum remains at a distance of 2 to 3 centimeters from the opening of the drainage tube and cannot plug it (at a later stage a foraminal hernia of cerebellum might develop either from hydrocephalus or infection in the cerebellum), whereas the roots of the cauda equina are prone to float into and block the opening of a tube in the spinal canal; should the tube be inserted into the spinal dura instead of being sutured flush with it, this possibility would be even more likely. It is much more difficult to maintain a drainage tube in the lumbar region and the chances of soiling the wound from excreta are always great. It is relatively simple to immobilize a drainage tube in the hollow of the neck by a big dressing. Either the tube can be attached to a bottle or, if the patient is too restless, the drainage bottle can be inserted into the dressing and lateral movements of the body need not be restricted. Anteroposterior movements are prevented by a check-rein from the forehead to the interscapular region. Moreover, it is relatively easy to maintain sterility of the skin in the suboccipital region.

In cases of meningitis following a mastoid infection, I should feel even more strongly that this type of cisternal drainage should be used instead of lateral drainage of the cisterna through a mastoid operative wound, as has been suggested and tried. Lateral drainage would be much more difficult to maintain uninterruptedly, because the cerebellar lobe lies against the dura and drainage through an infected mastoid would surely soon introduce an additional secondary infection of other organisms. Moreover, the patency of a lateral fistula would be a matter of chance instead of control. It need not, of course, be urged that a primary mastoid infection, which is feeding the meninges, should receive the earliest possible treatment independent of cisternal drainage.

It should be emphasized that drainage alone cannot cure meningitis. In the final analysis, the body must be able to combat the infection, and if this is impossible, drainage will be unavailing. Drainage can only help nature fight this battle by removing the intracranial pressure and by eliminating much of the infection. It is, therefore, not to be expected that any method is going to do more than reduce the high mortality rate which exists at the present time.

CONCLUSIONS

1. Early continuous drainage of the cisterna magna is advocated for the treatment of meningitis in which the infecting organism is staphylococcus and streptococcus.

2. Three of 4 cases so treated survived; 1 case of streptococcus viridans, 1 of streptococcus hæmolyticus, and 1 of staphylococcus aureus. In the unsuccessful case the organism was streptococcus hæmolyticus.

3. This method is not urged in other forms of meningitis because it is felt, though not proven, that the character of the inflammatory exudate would probably make drainage impossible.

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FIVE YEAR END-RESULTS OBTAINED IN CARCINOMA OF THE FEMALE PELVIC ORGANS WITH SPECIAL REFERENCE TO RADIUM AND X-RAY THERAPY[1]

By HENRY SCHMITZ, M.D., F.A.C.S., Chicago

FROM 1914 to 1923 inclusive 734 carcinomata of the female pelvic organs entered my clinic. The primary carcinomata numbered 584 and the recurrent carcinomata 150. The recurrences followed a preceding surgical excision of the cancer. All of the 734 cases were subjected to treatment with radium and X-rays. Since 243 cases have passed the conventional five year period it was deemed of interest to determine the curative value of radiation therapy in carcinomata of the female pelvic organs. If we apply the same rules to the cases treated with radiations as we do to those treated with surgery, the relative and absolute curabilities, also, can be determined for the radiation method of treatment. It was thought advisable to consider the primary and recurrent carcinomata separately.

THE PRIMARY CARCINOMATA

Table I shows the number of primary cases treated during each year and for the different regions. In the last column are given the percentages for each organ in this series.

To determine the method of treatment the cases were grouped. In Group I were placed the carcinomata in which the cancer after a physical examination was found to be clearly localized, without any evidence of either a second growth, an œdematous condition of the tissues immediately surrounding the tumor, an infiltration of the surrounding tissues, a fixation of the growth, or an invasion of the regional lymphnodes. A diagnosis of malignancy in this group can only be made with the microscope. The clinical evidence usually points to a benign disease. Group II comprises the cases in which doubt existed about the definite localization of the growth after a physical examination. An œdematous or doughy consistency of the paracervical tissues is felt on bimanual examination. Group III contains the cases with evidence of invasion of the surrounding tissues, organs, and regional lymphnodes. The tumor is definitely fixed. In Group IV those carcinomata were placed which had large necrotic ulcers or craters, had widely invaded surrounding tissue and organs or had advanced cachexia from auto-intoxication. A careful general physical examination was made in each case and X-ray pictures were taken in all advanced cases to determine bone metastases.

The indications for treatment were in Group I, radical surgical excision; in Group II, radium and X-ray and later on excision; in Group III, radium and X-rays; and in Group IV, palliative medicinal treatment.

Patients with Group I or Group II cancers, who had a complicating disease contra-indicating surgical intervention, were treated with radiations only. Exceptions to the general rules were made in cervical carcinomata. If the latter had been treated with radium and X-rays we did not subject them to a subsequent operation. The reasons were twofold: (1) We can apply to no other organ in the entire pelvis such large amounts of radium. The uterus is thereby entirely destroyed. A hard, fibrous atrophic uterus is all that remains after healing is completed following the radium destruction. (2) We must assume that the subsequent function of a cancerous organ locally healed from carcinoma by the rays will again cause irritation. Recurrences are frequent, if not the rule. The uterus is practically removed totally by the effect of the rays. It ceases to function. Total abstinence from coitus can be ordered and is usually maintained. The condition resulting from radiation therapy may be likened to a radiation panhysterectomy. The removal of such an apparently harmless uterus often lights up carcinoma. A subsequent operation after a local healing of a cervical carcinoma is therefore not indicated and unnecessary.

In carcinomata of the other pelvic organs,

[1] Read before the Chicago Gynecological Society, June 20, 1924. (For discussion, see p. 839)

radium must be applied in much smaller doses if we wish to avoid irreparable destruction. The result is a local degeneration of the carcinoma and not a destruction. The cancer cells are rendered dormant for an indefinite time. Local irritation or inflammation, however, may cause them to reassume activity. Therefore, if we wish to avoid recurrence or bring about an absolute cure, we must shut out the organ from subsequent function and irritation. A colostomy enables one to exclude the rectum. However, in the other regions we must resort to surgical eradication if we wish to assure healing.

We have discarded the grouping into operable, borderline, inoperable, and advanced, hopeless cases. The determination of operability or inoperability depends entirely on the subjective interpretation of the clinician. One needs only to study the various interpretations of the different clinicians on operability to prove this contention. For instance, Baisch extends operability of cervical carcinomata to cases with a positive invasion of one of the parametria. Obviously if we intend to compare the efficacy of the methods of treatment for carcinoma we must use a grouping which enables every one to give the same interpretation of the extent of the cancer disease.

From 1914 to 1918 inclusive 180 primary carcinomata were treated according to grouping and indications given in Table II. The exceptions have been stated in a previous paragraph. The cases of Group I had complicating diseases, as advanced Bright's disease, diabetes mellitus, discompensated heart disease, and so forth, hence were treated with radium and X-rays only. Therefore they are enumerated in Table III under Group I. The number of cases living were free of the disease, that is, were anatomically healed and subjectively well at the expiration of five years from the time of treatment. The clinical diagnosis was always corroborated by microscopic examination of excised tumor tissue.

Since the cervical carcinomata comprise the greater number of all the carcinomata we have made a more detailed study of them. Table IV shows the arrangement in groups and years.

In order to evaluate the results given in this table, I have collected the results obtained in other clinics. (See Table V.) From this table we may conclude that the five year end-results or absolute cures in the last three clinics with the combined radium and X-ray treatment are practically the same. On the other hand, the results of the other clinics using radium exclusively show marked discrepancies. This may be explained by the radical method of treatment with radium used by Kehrer who considers doses of 10 to 14,000 milligram element hours as the *Einschmelzungs dosis*, while Clark, Bailey and Healy employ from 3,000 to 5,000 milligram element hours of radium on the average. In the combined method of radium and X-ray therapy a 100 per cent erythema dose of X-rays is added to the radium dose, which is from 3,600 to 4,800 milligram element hours.

If we compare the results of Table V with those obtained with surgical methods, and take into consideration the operability percentage, then it is seen that the operability percentage in the clinics of Clark, Baily and Healy, Schmitz, and Doederlein is very low. It is high in all the others. However, high operability means an early and prognostically favorable cancer material. Obviously the clinics using radiation therapy have received a large number of advanced carcinomata. Hence the absolute curability percentage is low. The high relative curability percentage in my clinic probably resulted from the method of grouping. This, however, does not influence the end-results. (See Table VI.)

The observations which we have made on the efficacy of surgery and radiation are:

1. Surgery is the method of choice in the Group I cases. Poor surgical risks are treated with the combined radium and X-ray method of treatment.

2. If surgical treatment is used in the Group II cases it should be preceded by the application of radium and X-rays to render the cancer harmless and thereby increase the efficacy of the treatment. However, radiation therapy without subsequent surgery gives better permanent results in cervical carcinomata.

3. Radium and X-ray therapy is the method of choice in the clearly inoperable cases.

TABLE I. THE PRIMARY CARCINOMATA OF THE FEMALE PELVIC ORGANS

	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	Total	Per Cent
Vulva		1					2	1	1	2	7	1.2
Urethra			3	1	1				1		6	1.03
Vagina		1					1	4	4	2	12	2.06
Bladder	1	2		1	8	7	4	6	7	4	40	6.85
Rectum	4	6	6	14	13	6	9	13	18	14	103	17.65
Cervix	19	19	16	18	33	31	42	43	64	63	348	59.6
Corpus	3	1		2	2	4	3	6	1	5	27	4.61
Ovary	1		2	2	3	3	3	11	9	7	41	7.0
Total	28	30	27	38	60	51	64	84	105	97	584	

TABLE II. GROUPING AND INDICATIONS FOR TREATMENT OF PRIMARY CARCINOMATA OF THE FEMALE PELVIC ORGANS

Group	Physical Findings	Treatment
I.	The clearly localized, single growth.	Radical surgical excision.
II.	Suspicion of beginning invasion of tissues surrounding the growth.	Radium and X-rays and subsequent radical surgical excision.
III.	Multiple growths, infiltration of adjacent tissues, fixation of organ, or involvement of regional lymphnodes.	Radium and X-rays.
IV.	Extensive ulceration aad necrosis, advanced cachexia, extensive involvement, distant metastases.	Palliative and symptomatic treatment.

TABLE III. FIVE YEAR END-RESULTS IN PRIMARY CARCINOMATA OF THE FEMALE PELVIC ORGANS

Group	I		II		III		IV		Total	
	No.	Living	No.	Living	No.	Living	No.	Living	No.	Living
Vulva	1	1							1	1
Urethra	1	1			4	1			5	2
Vagina							1	0	1	0
Vesica	2	2	2	0	3	0	5	0	12	2
Rectum	4	2	5	0	22	3	12	0	43	5
Cervix	3	3	15	6	60	6	25	0	103	15
Corpus	2	1	1	0	2	0	2	0	7	1
Ovary	1	1			5	0	2	0	8	1
Total	14	11	23	6	96	10	47	0	180	27
Per Cent	78.5		26.0		10.4				15.0	

Number 37; living 17; per cent 46.0

Sixty out of a total of one thousand clearly inoperable and advanced cases were anatomically healed and subjectively well at the end of 5 years. If we exclude the hopeless and advanced cases of Goup IV then the percentage would be 7.4.

4. It is useless to treat the Group IV cases with massive doses of radiation with the intention of producing healing. Such cases should be treated symptomatically to arrest bleeding, discharge, and pain.

THE RECURRENT CARCINOMATA

The recurrent carcinomata treated between 1914 to 1923 inclusive are arranged in Table VII according to year and location. The re-

TABLE IV. FIVE YEAR RESULTS IN CERVICAL CARCINOMATA

A. Primary Carcinomata

Year	Group I			Group II			Group III			Group IV			Total		
	No.	Living	Per Cent	No.	Living	Per Cent	No.	Living	Per Cent	No.	Living	Per Cent	No.	Living	Per Cent
1914	1	1	.....	1	0	.....	14	0	.....	3	0	.....	19	1	5.3
1915	.....	.....	.....	4	3	.....	10	0	.....	5	0	.....	19	3	15.7
1916	1	1	.....	2	0	.....	8	2	.....	5	0	.....	16	3	18.7
1917	.....	.....	.....	4	2	.....	10	2	.....	4	0	.....	1[p]	4	22.1
1918	1	1	.....	4	1	.....	18	2	.....	8	0	.....	31	4	12.9
Total	3	3	100.0	15	6	40.0	60	6	10.0	25	0	.....	103	15	14.5

B. Recurrent Carcinomata

1914	1	0	.....	.....	.....	.....	3	0	.....	4	0	.....	8	.....	.....
1915	.....	.....	.....	2	.....	.....	6	0	.....	2	0	.....	10	.....	.....
1916	2	0	.....	.....	.....	.....	6	0	.....	3	0	.....	11	.....	.....
1917	1	0	.....	1	.....	.....	3	1	.....	2	0	.....	7	1	.....
1918	.....	.....	.....	1	.....	.....	6	1	.....	5	0	.....	12	1	.....
Total	4	0	.....	4	0	.....	24	2	.....	16	0	.....	48	2	4.2

TABLE V. COLLECTIVE STATISTICS OF FIVE YEAR CURES OF CERVICAL CARCINOMATA TREATED WITH RADIUM AND RADIUM AND X-RAYS

Clinic	Years	Group I			Group II			Group III			Group IV			Total			Method of Treatment
		No.	Living	Per Cent	No.	Living	Per Cent	No.	Living	Per Cent	No.	Living	Per Cent	No.	Living	Per Cent	
Clark, J. G.	1914–1918	.....	.....	.....	22	6	27.2	.....	.....	.....	118	6	5.1	140	12	8.6	Radium
Bailey and Healy	1914–1917	11	3	27.2	23	6	26.1	.....	.....	.....	121	8	7.1	155	17	9.2	Radium
Kehrer, E.	1915–1917	19	11	58.0	40	13	30.0	.....	.....	.....	70	12	17.3	129	36	27.8	Radium
Doederlein	1912–1918	110	48	43.6	136	31	22.0	340	23	6.7	169	1	.65	755	103	13.2	Radium and X-rays
Baisch	1914–1917	62	18	29.0	39	6	15.4	90	4	4.4	7	0	0	198	28	14.1	Radium and X-rays
Schmitz, H.	1914–1918	3	3	100.	15	6	40.0	60	6	10.0	25	0	0	103	15	14.6	Radium and X-rays

Total Number Groups I and II 480; well, 151 or 31.5 per cent.
Total Number Groups III and IV 1000; well, 60 or 6.0 per cent.
Total Number All Groups 1480; well, 211 or 14.2 per cent.
Total Number Groups I and II Radium 115; well, 39 or 33.8 per cent.
Total Number Groups I and II Radium and X-rays 365; well, 112 or 30.6 per cent.

TABLE VI. PERCENTAGES OF OPERABILITY AND RELATIVE AND ABSOLUTE CURABILITY OF CERVICAL CARCINOMATA FOR DIFFERENT METHODS OF TREATMENT

Clinic	Operability Per cent	Total Number	Number Cured	Relative Cures	Absolute Cures	Method of Treatment
Clark, J. G.	17	140	12	27.2	8.6	Radium
Bailey and Healey	22	155	17	26.4	9.2	Radium
Kehrer	45.7	129	36	40.7	27.8	Radium
Doederlein	32.6	755	103	30.3	13.2	Radium and X-Rays
Baisch*	51.0	198	28	23.8	14.1	Radium and X-Rays
Schmitz*	17.5	103	15	50.0	14.6	Radium and X-Rays
Johns Hopkins	52.1	387	102	46.5	26.6	Surgery
Stoeckel	70.6	350	98	35.4	26.6	Surgery
Graves	64.0	181	34	34.2	18.5	Surgery

*Cases treated surgically are not included.

currences occurred after a preceding surgical removal either radical or incomplete. The patients usully waited a long time before application for treatment. The presenting symptom was almost invariably a repetition of the symptom of the primary carcinoma. The delay in an earlier request for treatment was explained by the fact that the patient thought herself to be cured.

For the study of the efficacy of treatment the recurrent carcinomata were also grouped. (See Table VIII.)

TABLE VII. RECURRENT CARCINOMATA OF THE FEMALE PELVIC ORGANS

	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	Total	Per Cent
Vulva			1			3				4	8	5.3
Vagina	1										1	0.7
Urethra					1						1	0.7
Vesica	2			1	1	1			8	2	15	10.0
Rectum		1	2		2	2			2		9	6.0
Cervix	8	10	11	7	12	14	13	8	12	9	104	69.3
Corpus						1		2			3	2.0
Ovary		2	1			2		2	2		9	6.0
Total	11	13	15	8	16	23	13	12	24	15	150	

TABLE VIII. GROUPING AND INDICATIONS FOR TREATMENT OF RECURRENT CARCINOMATA OF THE FEMALE PELVIC ORGANS

Group	Physical Findings	Treatment
I	Local movable recurrence.	Radium and X-rays and excision.
II	Recurrence in adjacent tissues or organs, freely movable.	Radium and X-rays. Excision if practicable.
III	Local or adjacent recurrence with firm fixation.	Radium and X-rays.
IV	Recurrence with extensive necrosis; wide involvement; advanced cachexia; distant metastases.	Palliative and symptomatic treatment.

The 5 year end-results of the recurrent cervical carcinomata are given in Table IV. It is seen that Groups III and IV comprise 40 of the 48 cases. This proves the delay in applying for radiation treatment, the operability being 16.7 per cent. The total number of recurrent carcinomata from 1914 to 1918 inclusive is 63 with 5 five year cures, that is 7.9 per cent. One was a rectal carcinoma and four were cervical carcinomata. Group I numbered 4 cases; Group II, 4; Group III, 33; and Group IV, 22. The possible operability would be 12.6 per cent.

Therefore we may consider the results of radiation treatment of recurrent carcinomata in our series negligible—undoubtedly due to the great number of Groups III and IV cases. This observation does not agree with that made in recurrent mammary carcinomata for the same period. The total number was 60; 9 belonged to Group I with 6 five year cures, or 66.7 per cent; 9 to Group II with 3 five year cures, or 33.3 per cent; 23 to Group III with 2 five year cures, or 8.7 per cent; and 19 in Group IV with no cures. The operable cases of Groups I and II numbered 18 with 9 five year cures, or 50 per cent. The operability percentage is 30.1. In the total number of 60 we had 11 five year cures, or an absolute curability of 18.3 per cent. We may state that in the same period 31 primary breast carcinomata were treated with 9 five year cures, that is, an absolute curability of 29 per cent.

It seems to be advisable to examine the tissues and organs removed surgically by careful macroscopic and microscopic examinations. If the periphery of the removed tissue mass is not at least 3 centimeters distant from the carcinoma area the patient should be immediately subjected to radiation treatment. It is a surgical principle in the operations for removal of carcinomata to make the incision 3 centimeters distant from the periphery of the growth. We must apply the same rule to carcinomata of the female organs. If we cannot make the incision in healthy tissues, operative treatment is evidently incomplete and useless.

SUMMARY

The five year end-results of radiation treatment of primary carcinomata of the female

pelvic organs have been given. The absolute curability in a series of 180 cases is 15 per cent; the relative curability in 37 cases of Groups I and II is 46.0 per cent.

Similar statistics for cervical carcinomata from other clinics have been added. The radiation treatment of carcinomata of the female pelvic organs compares favorably with the surgical treatment if the percentages of cases suitable or not for operation are taken into account.

The grouping of carcinoma cases should be based on the results of the physical examination and not on the subjective interpretation of operability or inoperability.

The radiation treatment of recurrent carcinomata of the female pelvic organs has given only temporary subjective palliation, evidently due to the delay in applying for treatment soon after the operation. It is suggested that patients who have had incomplete surgical operations be subjected immediately after operation to radiation treatment. We may then succeed in improving the results of radiation treatment in this class of cases as shown in recurrent mammary cancers.

MALIGNANT EPITHELIAL TUMORS OF THE THYROID

With Special Reference to Invasion of Blood Vessels

By ALLEN GRAHAM,, M.D., F.A.C.S., Cleveland, Ohio
From the Departments of Surgery and of Pathology, Lakeside Hospital and School of Medicine, Western Reserve University, Cleveland, Ohio

NO attempt will be made to summarize the voluminous confusing literature concerning epithelial tumors of the thyroid. In 1921, Wilson[1] reviewed the literature and gave a complete list of references to articles that have appeared since the review by Mueller and Speese (1906), and some references not included by the latter authors. In reporting his experience with these tumors at the Mayo Clinic, Wilson states: "Correct early diagnoses of malignant tumors of the thyroid are made probably less frequently than of malignant tumors involving any other organ of the body." In 1922, Meleney[2] reported "A Metastasizing Malignant Tumor of the Thyroid," referred to the literature and drew this inevitable conclusion: "At present the diagnosis of malignant tumors of the thyroid is very difficult, and until more data are supplied the criteria of malignancy will be hard to find. Until that time the most accurate diagnoses will be made by the pathologist of greatest experience who has been able to check up his pathological observations with exact clinical follow-up data." Almost all authors emphasize the difficulties in diagnosis and no two agree on a satisfactory classification.

It is in connection with epithelial tumors that the greatest confusion and difference of opinion concerning the nature, the pathological diagnosis, and an appropriate terminology exist. This we believe may be attributed to the following:

1. The failure in the past to discriminate sufficiently between "normal" and "adenomatous" thyroid tissue.

2. The none too well appreciated importance of the rôle of the pre-existing adenoma in furnishing the starting point for a very high percentage of epithelial malignancies.

3. The great number and combinations of names, implying different pathological entities, applied by various authors, to what, in the vast majority of cases, is clearly one and the same fundamental pathological process.

4. The academically irreconcilable conflict between a purely morphological and a biological interpretation of the term "carcinoma."

5. The failure to take sufficiently into account the peculiarities of the thyroid as a tissue or special organ, in arriving at what constitutes malignancy.

Our personal experience with malignant epithelial tumors of the thyroid and the conclusions drawn from a recent intensive study, prompted by the uncertainty of pathological diagnosis in a number of cases and the failure to find a satisfactory solution in the literature, seems to offer a basis for some simple, practical suggestions that may be of interest. Certainly the present conceptions are immeasurably more satisfactory than any we have previously entertained.

In order to avoid misunderstanding it is necessary to state exactly what we mean by the following:

Carcinoma is intended to include all epithelial tumors that show any clinical or pathological evidence of malignancy.

Malignant adenoma is applied to any tumor that is or was an adenoma and has become malignant.

Malignancy is evidenced by one or more of the following: local invasion, recurrence (of the original tumor) after incomplete excision, metastasis, death of the patient due to the invasive character of the tumor.

With the above definitions in mind, this article is offered as a preliminary report of our observations on malignant tumors of the thyroid. The present discussion is limited to tumors arising from thyroid epithelium and excludes "parastruma," "struma postbranchialis," and squamous-cell epithelioma or carcinoma. Three cases of so-called mixed

[1] Wilson, L. B. Ann. Surg., 1921, lxxiv, 129.
[2] Meleney, F. L. Ann. Surg., 1922, lxxvi, 684.

tumor or carcinoma-sarcoma are also excluded, although their inclusion as carcinomata would strengthen rather than detract from our main conclusions. The chief object is to consider some special features of thyroid epithelial tumors and to call particular attention to a hitherto not sufficiently recognized nor utilized evidence or "criterion" of malignancy. Much detail has been omitted. This deficiency will be supplied in a series of subsequent articles.

The report is based on the material available at Lakeside Hospital from 1905 to 1922 inclusive and a few tumors received from other sources. The total experience with malignant tumors is mentioned for the purpose of showing the relative incidence of the various types of lesions and the relation of the epithelial tumors to the total number of malignancies. The incidence of malignancy based on thyroid specimens received in the laboratory (1915 to 1922) from the surgical division of Lakeside Hospital only, varies between 1 and 2 per cent. The total list includes the records of 134 patients in 12 of which a clinical diagnosis of malignancy was made but tissue was not examined. Of 122 tumors examined pathologically there are: 1 parastruma, 10 sarcomata, 3 tumors at present classed as carcinoma-sarcoma, and 108 epithelial tumors either malignant or suspicious. Only the latter group will be considered at this time.

The 108 epithelial tumors fall readily into four distinct groups on the basis of their gross and microscopic anatomy (Table I). It is to be noted that all of these tumors, formerly, have been diagnosed and considered, by ourselves and others, as malignant and have been designated and classified by the use of such terms as carcinoma, malignant adenoma, adenoma with early malignancy, and such qualifying terms as doubtful, early, suspicious, precancerous, etc. The use of these terms was the reflection of an uncertainty in our pathological diagnosis altogether too common to be satisfactory to ourselves or to the surgeon. There were too many instances in which we were unable to say with reasonable reliability whether the tumor removed was malignant or benign. This condition prevailed, chiefly, in connection with one type of lesion—adenoma. In conformity with the data now available, 43 tumors have been excluded from the list of 108 previously considered malignant.

The two scirrhous and the eight papilliferous adenocarcinomata are distinct types, grossly and microscopically. They are exactly comparable to similar lesions in other tissues and organs, and present no problem peculiar to the thyroid except that six of the papilliferous adenocarcinomata originated in adenomata. In the other two papilliferous and the two scirrhous we can neither prove nor disprove adenomatous origin, although the thyroid was adenomatous in each case. The six papilliferous adenocarcinomata that originated in adenomata are not included in the 55 malignant adenomata because this type of lesion, as well as the scirrhus, are essentially "single type" tumors and do not invade the blood vessels so far as our experience goes. Malignant adenoma, on the other hand, is usually a "multiple type" tumor and invariably invades the blood vessels.

Concerning papilliferous adenocarcinoma, it is necessary to state that a distinction is made between those tumors which, grossly and microscopically, are made up almost if not entirely of papillomatous tissue, usually in connection with a cyst, and those solid adenomata which among various other histological pictures present localized areas of papilliferous growth by no means predominant. The former only are designated papilliferous adenocarcinomata, and are primary "lymphatic invaders"; the latter are designated malignant adenomata and are primary blood vessel invaders. It is important to preserve the distinction.

Scirrhous and papilliferous adenocarcinomata will be omitted from further discussion in the present article since their diagnosis, classification, and the determination of malignancy rests on the usual pathological standards.

In the 55 carcinomata (designated malignant adenoma) and the 43 adenomata, formerly considered malignant, but now classed as benign, will be found the key to the solution of the problem of thyroid epithelial malignancy. A study of these cases leaves little room for doubt that we are dealing with va-

rious stages of one pathological process, namely the transformation of benign to malignant adenoma, and the only question is: what constitutes malignancy? Where and how shall the line be drawn between these two groups of tumors? These questions bring us to a somewhat detailed consideration of some of the most important features of these lesions.

MORPHOLOGY OF CELLS AND TISSUE AS EVIDENCE OF MALIGNANCY

In the series of 98 tumors under discussion we find all conceivable steps, stages, and degrees in the growth, differentiation, and degeneration of fetal, intermediate (or mixed) and colloid adenoma. In addition we find all grades of transition of the original adenoma into all types and combinations of morphological cancer mentioned in the literature, except pure papilliferous adenocarcinoma and pure scirrhous carcinoma. These various combinations of adenoma and morphological cancer are present in the series of tumors and frequently in a single tumor. The quantity of tissue that may be recognized morphologically as cancer is in inverse proportion to the remnant of the original adenoma. In some cases there are only a few small scattered areas; in other cases the cancerous change is more or less generalized, but rarely is the adenoma remnant completely lost even in advanced cases.

The ultimate microscopic appearance of the tumor is determined by a number of factors among which may be mentioned: the character and condition of the original adenoma; the duration of the lesion; the rate of growth; the character and degree of reaction simultaneously or subsequently initiated in the supporting stroma, scar, or capsule; the blood supply; and the degenerative changes that have taken place. There may be, and doubtless are, other factors difficult or impossible to evaluate. The above circumstances afford an interminable variety of histological pictures for the group and for individual tumors. It is with rare exceptions that one histological form prevails throughout the whole tumor.

In view of the innumerable variations and combinations of histological alteration in the cells and tissues of these tumors, individually and as a series, it would seem that the reliability of diagnosis on the basis of pure morphology would depend very largely on the personal experience of the observer with these lesions. It is no doubt a fact that certain types of histological abnormality (Figures 11, 12, 18) may be in themselves sufficient grounds for a diagnosis of carcinoma or malignant adenoma, for our material seems to indicate that certain of these histological pictures are invariably accompanied by other evidences of malignancy, such as invasion of the capsule, invasion of the blood vessels, recurrence, or metastasis. It remains for each individual, on the basis of his experience, to determine how many different types of histological abnormality may be reasonably accepted as indicative of malignancy. In the 98 tumors under discussion a diagnosis of carcinoma or malignant adenoma can be made with confidence on the morphology of the cells and tissue in 30 to 40 per cent of the cases. In the remaining 60 to 70 per cent, malignancy can be neither affirmed nor excluded on such basis. If we consider the 55 tumors designated malignant adenoma, only, diagnosis may safely rest on morphology in about 60 to 70 per cent but there still remains a percentage in which the microscopic appearance of the tissue cannot be relied upon, although the tumors may show the grossest kind of malignancy otherwise. The most evident inadequacy of microscopic appearance as a criterion of malignancy becomes apparent in connection with the 43 adenomata formerly considered malignant but now classed as benign. Here the character of the cells and tissue can be duplicated in any number of tumors known to be malignant, and yet in none of these 43 adenomata has there been any clinical or pathological evidence of malignancy other than the suggestive or questionable histological alteration; and there have been no recurrences, metastases, or deaths due to the disease in any of the patients traced. We emphasize again that these 43 tumors have been previously diagnosed as malignant, on morphological grounds.

It is very probable that, in the past, others as well as ourselves, have placed too much

reliance upon the histological character of the cells and tissue as an index of malignancy. In the light of our later experience and a study of the end-results we have come to the conclusion that, so far as diagnosis is concerned, it makes very little practical difference what the tumor looks like under the microscope, whether the cells be large or small, flat, cuboidal, or cylindrical, fetal or adult, differentiated or undifferentiated, deeply staining or faintly staining; whether mitosis be abundant or absent; whether there be colloid or absence of colloid; whether the cells be arranged in a single layer or multiple layers in the vesicle; whether the vesicle wall be thrown into papilliferous folds or not; whether the cells be arranged in follicles, sheets, masses, columns, or alveoli; whether the stroma be abundant or scanty; whether degenerative changes be absent or extreme—all of these things are a part of the histology but are not the most important evidences or signs by which to recognize malignancy. The malignancy depends upon the tendency or capacity of the tumor to invade locally, cause local destruction, recur after operation, give distant metastases, and finally to result in the death of the patient. There can be no metastasis until there has been some kind and degree of local invasion. Therefore, local invasion is the most important index of malignancy.

INVASION OF SURROUNDING TISSUE AS EVIDENCE OF MALIGNANCY

Thyroid carcinomata not arising in adenomata have no capsule. When tumors of this character grow beyond their site of origin, they follow the tissue planes and spaces, find ready access to the lymphatic system and hence metastasize chiefly to the regional lymph nodes.

Carcinomata originating in pre-existing adenomata are, primarily, encapsulated. Subsequently they may invade and cause more or less extensive but rarely complete destruction of the capsule. After the capsule has been penetrated or perforated, further growth and extension of the tumor into the surrounding tissues and lymphatics occurs in a manner similar to that obtaining in those cases not originating in adenoma. As long as these tumors are still within their original capsule there is no invasion of the lymphatics, quite irrespective of their microscopic appearance. They may be malignant, nevertheless, and cause the death of the patient as a result of distant metastasis through the blood stream.

INVASION OF THE BLOOD VESSELS AS EVIDENCE OF MALIGNANCY

It has been known for years in connection with individual cases that well advanced carcinoma of the thyroid shows a marked tendency to break into the blood vessels (usually veins) and to grow within their lumina toward the heart. In some reported cases, "tumor thrombus" has extended continuously from the thyroid tumor to the right atrium; in a number of cases it has been found to extend to the innominate vein or superior vena cava; in a still greater number of cases it has been found in the jugular and thyroid veins. Our first recognition of this phenomenon in a well marked degree was in 1914 (11074).

The tendency to invade blood vessels accounts for the high degree of frequency of metastasis to the lungs and also for the relatively less frequent but still striking distant metastases of which those to bone are common. This peculiarity of thyroid tumors has a close parallel in hypernephroma.

Invasion of the blood vessels is not a strange phenomenon when one considers that at least 90 per cent (Table) of malignant (epithelial) tumors originate in a pre-existing adenoma and that even in the early stages of the transformation of benign to malignant lesion the epithelial cells lie closely on the blood vessel endothelium with little or no fibrous stroma between. It is a simple matter for the tumor cells to break into the endothelial lined spaces, either spontaneously or as the result of trauma, and grow there locally, form tumor thrombi extending in continuity a greater or less distance along the blood channel, or for clumps of cells or portions of tumor thrombus to break off and be transported by the blood stream to distant parts of the body.

Naturally the first lodging place should be the lungs. Should the embolus pass the pulmonary capillaries it might lodge in any dis-

TABLE I.—ONE HUNDRED-EIGHT EPITHELIAL TUMORS

	No. of cases	Types	Adenomatous origin		Invasion of blood vessels	Result*		
			Positive	Not proved		Traced	Dead	Living
Carcinomata	2	Scirrhus	0	2	none	2	2	0
	8	Papilliferous adenocarcinoma	6	2	none	7	1	6
	55	Malignant adenoma	53	2†	100%	37	17	20
	65	Totals	59 92.4%	6 7.6%	55/65 84.7%	46	20	26
Adenomata formerly classed as malignant, now benign	43	——	43	——	none	16	1‡	15

*Under "Result" the figures given are in accordance with our records as of January 1, 1924. They are not considered complete nor final but are used solely to indicate the relative malignancy of the various types of cancer.

†One of these was incomplete excision of recurrent tumor (primary operation elsewhere); the other, on exploration, was found to be inoperable and a specimen was excised for microscopic examination. Accepting these two as "Not proved" we still have 92.4 per cent positive adenomatous origin of cancer.

‡Hospital death, second day after operation; tumor not malignant.

tant tissue or organ (most commonly bone) and there develop a secondary or metastatic growth. Should the embolus not pass the pulmonary capillaries, secondary or metastatic nodules may develop in the lungs. This might be the only metastasis or from it tertiary nodules may be set up in various parts of the body either through the blood or lymph channels. In either case the morphological character of the metastases corresponds, usually, to some portion of the original metastasizing tumor.

The recognition of invasion of the blood vessels is not so difficult as might appear on first thought. It is not so subtle as to require innumerable blocks of tissue for examination nor, for practical purposes, are serial sections necessary. The chief requirement is for the pathologist to know that such a sign of malignancy exists and exists with such a high degree of frequency as to be worthy of recognition as a working rule. It then becomes a mere matter of looking for this peculiar manifestation of thyroid epithelial malignancy. From the standpoint of the pathologist alone, with no knowledge of the clinical or operative findings, the gross tumor should be sufficient to direct the attention of one experienced in these lesions to a search for invasion of the blood vessels. Examination of the thyroid veins, the veins of the capsule, and the veins of the tumor immediately beneath the capsule will disclose gross thrombus and gross erosion when present and this can be verified easily under the microscope. When not advanced to the degree of gross lesion, a few blocks through the capsule and tumor tissue and from any suspicious area or areas within the tumor will usually suffice for the microscopic demonstration of the invasion.

Naturally the degree or extent of invasion is variable just as is the case with other evidences of malignancy. Four grades may be noted: (1) gross thrombus (Figure 22), (2) gross erosion, (3) microscopic—tumor cells or tumor tissue, within the blood vessels (Figures 12, 20, 21); (4) microscopic—erosion of the walls of larger blood vessels other than capillaries or sinuses (Figure 19).

The character of the tissue found within the blood vessels corresponds morphologically to some portion of the original tumor and is quite independent of the presence or absence of what might be called "morphologic cancer." (Compare Figures 13 to 21 with Figures 5 to 12.) It is conceivable that varying degrees of differentiation and dedifferentation might progress in tissue growing within the blood vessels and thus afford as great a variety of histological pictures as is commonly found in the original tumors. On the other hand it is equally conceivable that in a given case portions of tumor tissue of totally different histological appearance might grow into the blood vessels without essential morphological alteration. Which of these possibilities predominates in these thyroid tumors we are not prepared, at present, to state. The question is worthy of further observation and future investigation.

The incidence of blood vessel invasion has been a surprise. We are not aware that there has been any effort made to determine the incidence in a series of cases, nor to utilize the fact of invasion as a means of distinguishing between benignancy and malignancy. As previously noted, the only malignant epithelial tumors in which we have failed to find invasion of the blood vessels have been scirrhous and papilliferous adenocarcinomata, which together represent about 15 per cent of the total, and are primary lymphatic invaders. Blood vessel invasion has been as consistently absent in these two groups as it has been constantly present in all other epithelial malignancies.

Referring again to the 55 carcinomata, designated malignant adenomata, and the 43 adenomata formerly considered malignant but now classed as benign, it may be stated that in the former group invasion of the blood vessels has been noted in all cases, whereas in the latter it has not been observed in any case. When it is recalled that in the latter group the morphological character of the cells and tissue is strongly suggestive of early malignant adenoma or beginning adenocarcinoma, and that in the former group (55 malignant adenomata), there are a number of cases in which the morphology cannot be relied upon (Figures 5 and 6), the question of blood vessel invasion may be the determining factor in diagnosis. The tumors may be entirely encapsulated in both instances.

The greatest value of invasion of the blood vessels as an aid to diagnosis is in those encapsulated tumors (adenomata) in which other evidence of malignancy is wanting and the microscopic appearance of the cells and tissue is not sufficient ground for a decision.

EXPLANATION OF ILLUSTRATIONS

In Figures 1 and 2 we present photomicrographs of the thyroid of a fetus at 3 months for comparison with Figures 3 and 4, taken from a single encapsulated tumor that is malignant.

Figures 3 to 12 were taken from a single encapsulated tumor, showing various stages in the transformation of fetal adenoma to carcinoma. According to our conception this tumor was originally a fetal adenoma which in the course of time has undergone a high degree of differentiation (Fig. 5). At some time in its life history there ensued another change of an entirely different character, the end-result of which is shown in Figures 11 and 12, with Figures 6 to 10 representing intermediate steps in the process. The quantity of tissue as shown in Figures 11 and 12 is relatively small. More than half of the tumor is made up of tissue such as that shown in Figures 5 to 10. Note how closely some areas resemble the thyroid of a fetus (compare Figures 3 and 4 with Figures 1 and 2). Other areas (Fig. 9), resemble some thyroids seen in exophthalmic goiter. From a purely morphological standpoint many of the microscopic pictures in this series (Figs. 3 to 12) can not be recognized as cancer. One would not hesitate to say that Figures 11 and 12 are cancer. On the other hand Figures 5, 6 and 10, from the same tumor, are identical, morphologically, with any number of benign fetal and colloid adenomata. That Figure 5 may be malignant is difficult to believe from its histological appearance; nevertheless its exact counterpart is found in abundance in the thrombosed thyroid veins of this case (Figs. 13 and 14).

In Figures 13 to 21 we have a series of photomicrographs of tissue completely within thrombosed thyroid veins, such as that shown in Figure 22, *C*. Note the many areas that cannot be recognized, morphologically, as cancer. Note also the variety of histological pictures present in the veins of a single case.

Figure 22 is a photograph of a gross specimen from which all photomicrographs, except Figures 1 and 2 were made. Figures 3 to 12 are from the malignant tumor *A*. Figures 13 to 21 are from thrombosed thyroid veins (Figure 22, *C*). *B* is a benign fetal adenoma the microscopic appearance of which is shown in Figures 23 and 24.

In Figures 23 and 24 we have photomicrographs of the benign tumor (Fig. 22, *B*). Figure 23 shows partially differentiated fetal adenoma. Figure 24 shows a histological variation frequently seen in tumors known to be malignant, yet this particular tumor is entirely encapsulated, shows no gross or microscopic invasion of the capsule, and no invasion of the blood vessels. It is therefore benign.

The ultimate reliability of invasion of the blood vessels as a point of differentiation between benign and malignant adenomata is a matter for the future, but on the basis of our experience to date it seems well worthy of considerable confidence.

CONCLUSIONS

1. At least 90 per cent of malignant tumors arising from thyroid epithelium have their origin in pre-existing adenomata (Table I).

2. The morphological character of the cells and tissue is an unreliable basis for the determination of malignancy of thyroid epithelial tumors.

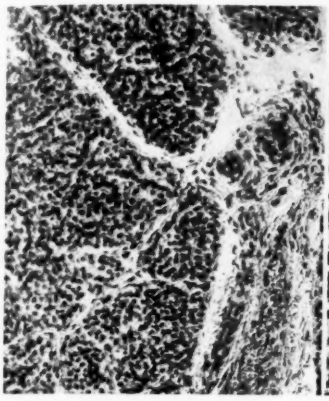


Fig. 1. Thyroid of fetus. X100.

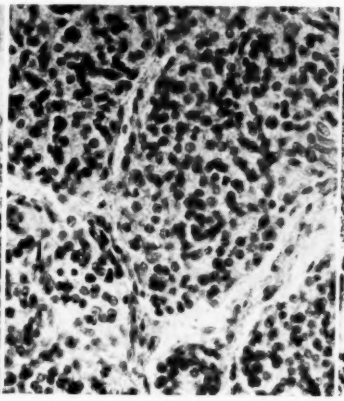


Fig. 2. Thyroid of fetus. X250.

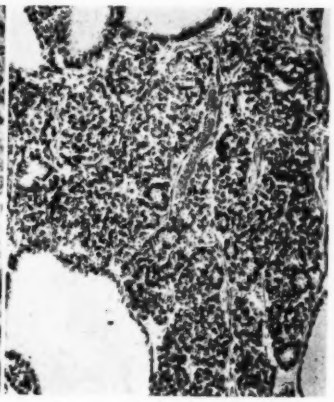


Fig. 3. Fetal adenomatous area in malignant tumor. X 100.

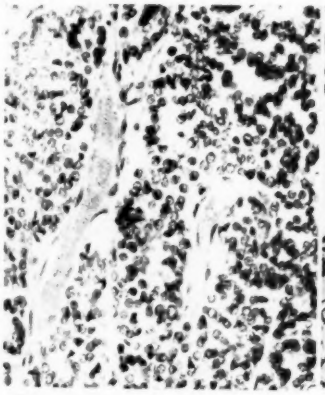


Fig. 4. Same specimen as in Figure 3. X250.

Fig. 5. Colloid adenomatous area in malignant tumor. X100.

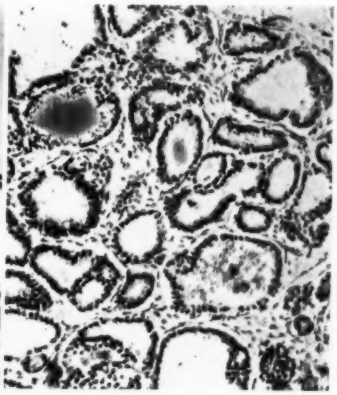


Fig. 6. Specimen from malignant tumor. X100.

Fig. 7. Specimen from malignant tumor. X100.

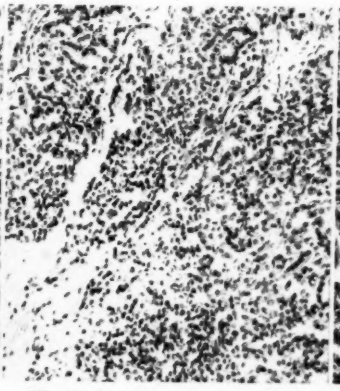


Fig. 8. Specimen from malignant tumor. X100.

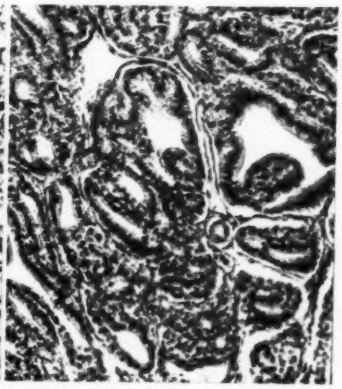


Fig. 9. Specimen from malignant tumor. X100.

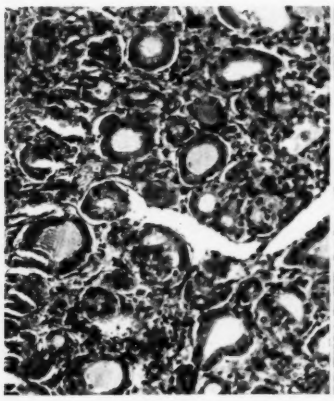


Fig. 10. Specimen from malignant tumor. x100.

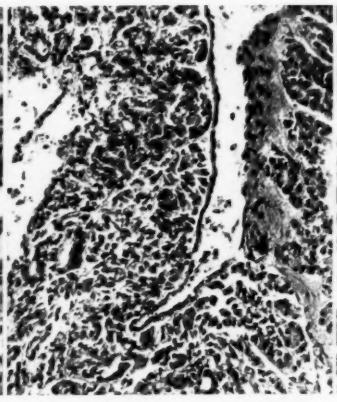


Fig. 11. Specimen from malignant tumor. x100.

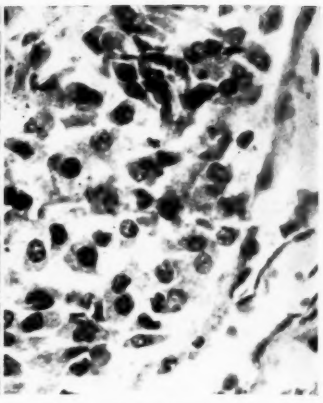


Fig. 12. From same specimen as in Figure 11.

Fig. 13. Tissue in vein. x100.

Fig. 14. From same specimen as in Figure 13. x250.

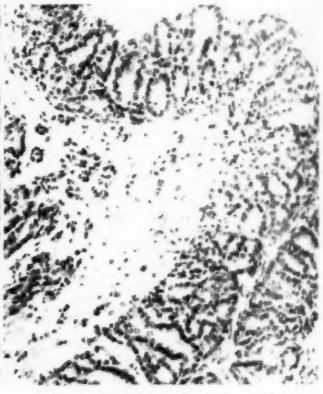


Fig. 15. Tissue in vein. x100.

Fig. 16. Tissue in vein. x100.

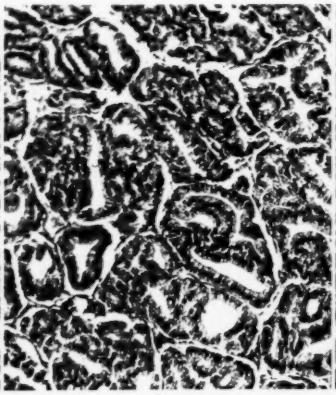


Fig. 17. Tissue in vein. x100.

Fig. 18. Tissue in vein. x100.

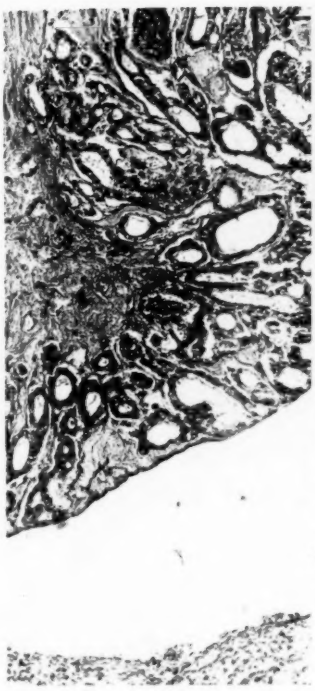


Fig. 19. Erosion of vein wall. x100.

Fig. 20. Thrombosed vein. x100.

Fig. 21. Tumor tissue in vein. x100.

3. The malignancy of thyroid epithelial tumors depends upon their tendency or capacity to invade the capsule, surrounding tissue, lymphatics, or blood vessels.

4. The most constant single indication of thyroid epithelial malignancy is invasion of the blood vessels.

5. Scirrhous and papilliferous adenocarcinomata are the only two types of epithelial malignancy in which invasion of the blood vessels has not been observed. These two types together constitute about 15 per cent of the total and are primary lymphatic invaders.

6. Epithelial tumors that are encapsulated and show no invasion of the blood vessels are benign, irrespective of their microscopic appearance otherwise.

7. Epithelial tumors in which one finds invasion of the blood vessels cannot be regarded as entirely harmless, irrespective of their microscopic appearance.

8. The term carcinoma is proper for epithelial tumors of the thyroid that are malig-

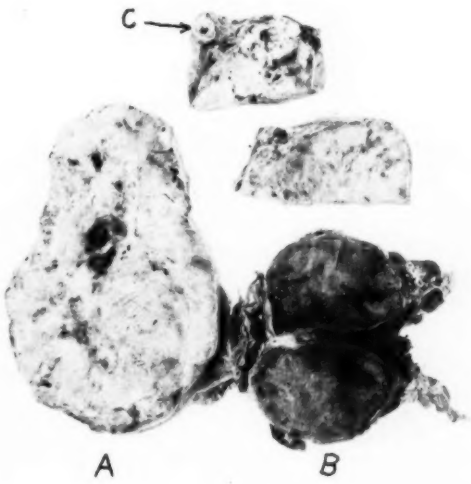


Fig. 22. Path. No. 10447. *A*, Malignant adenoma; *B*, benign adenoma; *C*, thrombosed vein.

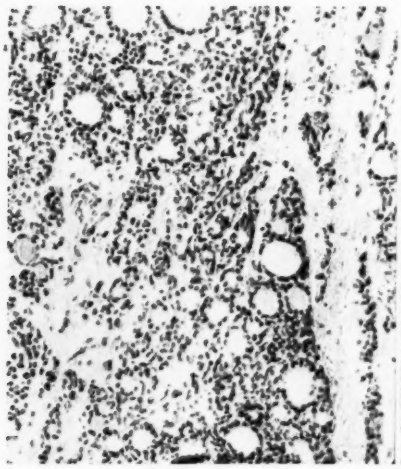


Fig. 23. Partially differentiated fetal adenoma (Fig. 22, *B*). x125.

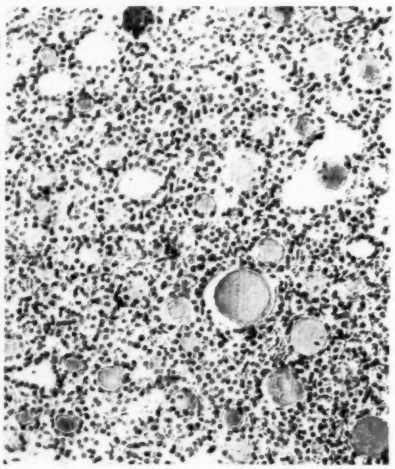


Fig. 24. Benign adenoma (Fig. 22, *B*). x125.

nant regardless of their microscopic appearance. The term malignant adenoma is useful and convenient for the purpose of denoting a subgroup under carcinoma but is not, strictly speaking, correct terminology. Such terms as *wuchernde struma*, proliferating adenoma, metastasizing adenoma, metastasizing colloid struma, metastasizing colloid goiter, and "metastasizing normal thyroid" are confusing, misleading, inaccurate, serve no useful purpose, and should be eliminated.

9. In view of the present available data the diagnosis and classification of malignant epithelial tumors of the thyroid present no greater difficulties and require no more complicated nomenclature than is commonly encountered in other organs and tissues of the body.

I wish to express my indebtedness to Dr. Crile whose extensive surgical material, almost exclusively, furnished the basis for this study; to the Cleveland Clinic for the end-result in many cases; and to Dr. H. T. Karsner for his kindly criticism, much valuable advice, and many helpful suggestions in the preparation of the manuscript.

OSTEOCHONDRAL FRACTURE OF THE KNEE JOINT

By ARTHUR KRIDA, M.D., F.A.C.S., New York
Assistant Surgeon to Out Patients, Hospital for the Ruptured and Crippled

THE purpose of this paper is to describe as a clinical entity an injury of the knee joint which corresponds in some particulars to Koenig's osteochondritis dissecans, and to show that it consists of three phases, the last phase being that of a free osteocartilaginous body.

The condition occurs usually in young adults, and is produced by a direct blow on the knee. The trauma produces an osteochondral fracture of a section of the articular portion of the internal condyle without primary displacement of the detached fragment.

THE FIRST PHASE

Whether from an inherent repair defect of the cancellous tissue of the condyle, or which seems more likely, from failure to provide the extraneous conditions of bony union, the fragment remains partially or nearly wholly separated, but still occupies its original situation in the condyle. The fragment has an irregularly oval outline, and its edges are serrated. It is loosely united to the underlying condyle by connective or fibrous tissue. This first phase of the fracture of the joint corresponds essentially with osteochondritis dissecans.

THE SECOND PHASE

In the course of time, the crater in which the fractured fragment is imbedded may become lined with cartilage, as does also the deep face of the detached fragment. The fragment is now entirely loose, but still maintains its position in the condylar pit.

THE THIRD PHASE—FREE OSTEOCARTILAGINOUS BODY

Under certain conditions, a subsequent trauma dislodges the fragment and it becomes free in the knee joint. If the displacement occurs during the first phase, the freed body consists of cartilage on one side and bone on the other. It subsequently becomes entirely covered with cartilage. The crater in the condyle may also grow a lining of cartilage.

DIAGNOSIS

The diagnosis in the first phase would depend upon the X-ray demonstration of the picture that has been described as characteristic of osteochondritis dissecans.[1] It is interesting to note that such X-ray demonstration could not be determined either prior or subsequent to operation in the first of the cases reported below, in X-rays taken in the usual manner. Since the fracture is usually posterior to the median plane of the condyle, it is easy to see why it may be missed.

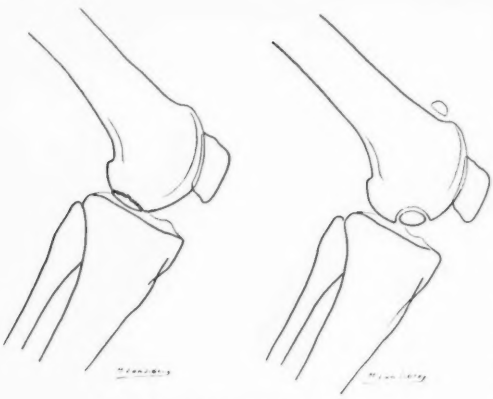
In the second phase the delineation of the fragment is more distinct. In the X-ray it looks like an area of condensation in the substance of the condyle. The diagnosis of the third phase requires no comment.

TREATMENT

If it be assumed that no inherent repair defect resides in the cancellous tissue of the condyle, and if the diagnosis could be made reasonably soon after the fracture, it would seem logical to create the conditions favorable to repair by relieving the joint of function. That such a diagnosis will be made sufficiently early for one reason or another, in any considerable percentage of cases, is unlikely. From a practical standpoint, therefore, the treatment is very apt to resolve itself into arthrotomy.

It will be seen that an adequate exposure of the joint is necessary. The incision employed in the 3 personal cases was a curved antero-internal incision beginning at the tibial tubercle, curving inward to avoid the fat pad, then outward toward the supero-internal angle of the patella, then upward and inward, following the intermuscular plane between the rectus femoris and the vastus internus. The

[1] A. H. Freiberg. Osteochondritis dissecans. J. Bone & Joint Surg. 1923, v, No. 1.



First and second phases.

quadriceps pouch is widely opened to its upper border. The patella is then displaced outward over the external condyle, and the joint flexed. This gives an adequate exposure of all parts of the joint except the small posterior compartment. In suturing, the various layers are approximated with some care. The convalescence is easier than that following a split patella incision.

The following 4 cases are reported as illustrative of the three phases of osteochondral fracture described above. The first 3 of these cases were personal cases and the last is a case operated upon by Dr. E. E. Van Derwerker, assistant surgeon at the Hospital for the Ruptured and Crippled, to whom I am indebted for the notes of the case.

CASE ILLUSTRATING THE FIRST AND THIRD PHASES

CASE 1. B. P., age 28, male, single, seaman, was seen first on November 12, 1923.

History. On June 20, 1923, while working inside of a boiler on board ship he struck his left knee with some force against the side of the boiler. The knee was slightly swollen the next day but he was given a light job to do and therefore did not lay off work.

In a few days he noticed that in walking he would have a sudden catch in the knee and at such times he would have to stop and manipulate the knee in order to get it going again. These attacks became so frequent that in August, 1923, he had an operation on the knee for the removal of two loose bodies which he states could be felt. Only one of these was successfully removed, the other not being found.

He states that since the operation this second body has traveled all about the joint, and that two weeks ago he had a slight sprain of the knee after which the body localized on the postero-internal aspect of the joint. He states that at the present time there is discomfort of this region and that he has a catch similar to the condition that prevailed previously. He also notes a slight atrophy just above the knee.

Examination shows a young man in good condition who presents a 1½ inch scar of operation on the inner aspect of the left knee. There is some evident shrinkage of the quadriceps just above the knee joint. There is some fullness in the region of the infrapatellar pad of fat. There is an old and indistinct burn scar on the outer side of the knee, together with slight knock-knee deformity.

The movements of the joint are complete in all directions and the stability is good. At the posterior aspect of the joint almost on a plane with the internal surface of the lower extremity and at a horizontal plane about ¾ inch above the tip of the condyle and just in front of the sartorius tendon insertion there is an indistinct, partially movable, slightly tender, hard mass about ¾ inch in diameter which disappears when the joint is flexed.

The X-ray shows the presence of a shadow corresponding in situation to the loose body described above.

Conclusions. While the presence of a loose body in the posterior compartment of the joint was definite it seemed to me, in view of its position, that it did not entirely account for the instability and repeated locking of the joint. I therefore determined to first try and get this small bit out through a small postero-internal incision, and then to explore the joint anteriorly.

Operation was performed at the U. S. Marine Hospital, No. 70, November 14, 1923. A 1-inch incision was made in the postero-internal aspect of the left knee in the region where the supposed loose body was felt. The joint capsule was opened and the surrounding joint space exposed. No foreign body was found. The incision was closed.

A typical antero-internal incision was then made as above described. The synovia as a whole was normal in appearance. Lying on the nethermost portion of the internal condyle and slightly behind the midline, and imbedded in its surface, was an irregularly oval osteocartilaginous body about ¾ inch in its greatest diameter and about ⅛ inch thick. The condylar pit was lined with granulation tissue and cancellous bone. This body was attached only at its posterior portion by soft fibrous tissue, the whole anterior portion being free. This was excised and the rest of the joint explored for additional loose bodies of which none were found. The posterior compartment could not be thoroughly explored. The joint was then closed in layers and firmly bandaged over cotton and placed in a Thomas splint.

January 2, 1924. The patient has been discharged from the hospital three weeks after operation, the incision having healed by primary union. On account of persistent discomfort in the region of the loose body in the posterior compartment which I

Lateral and anteroposterior roentgenograms of knee in Case 2.

failed to find at the first operation, I reopened this joint posteriorly through a 3-inch incision, on January 2, 1924. A ¼ inch in diameter osteocartilaginous body was found imbedded in the capsule of the joint and projecting slightly into it. This was shelled out and the incision closed.

February 4, 1924. The patient has been walking about without discomfort and he states that the locking sensation and instability have been entirely relieved. There is still some evident shrinkage of the quadriceps muscle.

CASE ILLUSTRATING THE SECOND AND THIRD PHASES

CASE 2. J. S., age 24, male, single, seaman, was seen first on January 7, 1924. His complaint was of a movable body in the left knee joint.

History. Three months ago while going along the ship he struck his left knee against an iron projection, the outer side of the knee being struck with some force. There was not very great immediate pain, but about 4 days later he felt a sudden severe pain on the outer side of the knee, the knee locked, began to swell, and for 3 weeks he could not get it straight. At the end of this time, the knee was strapped and he apparently got quite well. After this time, he had 5 or 6 attacks of locking with swelling, pain, and disability. One week ago he noticed a movable loose body just above the knee cap, which he states moves all about the knee.

Examination shows that there is a visible enlargement in the suprapatellar pouch. There is no effusion and no infiltration. The enlargement is found to be due to the presence of a movable, smooth, painless, hard body about ¾ inch in diameter which can be displaced to any portion of the suprapatellar pouch, otherwise the knee is not abnormal on physical examination.

The X-ray shows the presence of the above described body in the suprapatellar pouch about 1 inch above the patella on the inner side. It also shows apparently imbedded in the substance of the internal condyle another loose body which is about ½ inch in transverse diameter and seems to be lying in the condyle more towards its posterior portion.

Conclusions. The condition appeared to be osteochondral fracture, with one attached and one free osteocartilaginous body.

Operation was performed at the U. S. Marine Hospital, No. 70, January 9, 1924.

A typical antero-internal incision was made. The synovia was opened and it was seen that there was a moderately increased amount of fairly thick straw-colored fluid. Lying in the suprapatellar pouch is a 1 inch in diameter, smooth, osteocartilaginous body. This was removed. The patella was then displaced over the external condyle and the joint flexed, exposing its interior. Lying on the lower surface of the internal condyle and somewhat posteriorly to the midline, was a ¾ inch in diameter osteocartilaginous body which was loosely imbedded in a depression of similar size in the condyle, which depression was also lined with smooth cartilage. This body was attached by a thin layer of fibrous tissue about ⅛ inch in diameter. It was removed. At the edges of the depression the cartilage was fairly loose in two situations and these two loose bits were removed by excision. The synovia, the fat pad and the semilunar cartilages appeared to be normal.

The joint was closed in layers and bandaged over a thick cotton dressing.

January 24, 1924. The patient had been walking about the ward, the incision having healed by primary union. He was discharged from the hospital to return to work.

TWO CASES ILLUSTRATING THE THIRD PHASE

CASE 3. W. W., age 50, male, single, was an engineer.

History. Five weeks ago he struck his right knee against a metal pump with some considerable force. There was no immediate disability and he went on with his work. Two days later disability developed, consisting of pain and swelling in the knee, and inability to get it straight. He was treated by bandaging. Pain, swelling, and disability have continued without change until the present time.

Examination shows that the right knee joint as a whole appears moderately enlarged. He walks with a limp and with the knee held at an angle of 160 degrees. The enlargement is found to be due mainly to intra-articular effusion although there is some slight infiltration on the inner side of the knee. Movements of the knee are from 160 to 100 degrees. Stability is good. There is rather marked tenderness on pressure over the inner side of the knee, particularly over the articular surface of the internal condyle. There is marked pain on outward rotation of the leg on the thigh. Lying to the inner side of the condyle and apparently in the condylar face is a loose fragment which is probably a free body.

X-ray examination of the right knee joint shows two osseous shadows one above and one below the patella within the knee joint. The size of each is about that of a lima bean.

Conclusions. A diagnosis was made of osteochondral fracture of the knee joint with free bodies.

Operation was performed at the U. S. Marine Hospital, No. 70, March 3, 1924. A typical antero-internal incision was made. One smooth ¾ inch in diameter oval osteocartilaginous body was free in the suprapatellar pouch. This was removed. The synovia of the pouch was normal in appearance. At the upper portion of the pouch there were several irregularly transverse septa which were not disturbed. The patella was displaced over the external condyle and the knee flexed, during which procedure a ¾ inch in diameter oval osteocartilaginous body shot out of the wound. This body was not as smooth as the first one, and had a somewhat studded appearance, but was entirely covered with cartilage. Upon flexing the knee to 90 degrees, it was seen that the articular cartilage on the external surface of the internal condyle was rather markedly roughened from a point well in front of the midline backward, the roughened area terminating in a portion of the condyle which was entirely denuded of articular cartilage. This latter area was about ½ inch in diameter and was situated at the extreme posterior portion of the condyle and was somewhat depressed. Overhanging the depression was a somewhat loosened fringe of articular cartilage which was excised. The area of cartilaginous roughening on the condyle was apparently due to constant attrition of the second of the above mentioned loose bodies which apparently had been situated just in front of the anterior crucial ligament.

The internal semilunar cartilage was then excised. A ½ inch reduplicated synovial fringe in the lower portion of the quadriceps pouch was excised. The ligamentum mucosum was divided and the external portion of the joint was inspected and found to be apparently normal. The fat pad and alar ligaments were not enlarged except the portion of the alar ligament on the inner side was thickened and fibrosed, and this was excised.

The joint was closed in layers.

The patient was discharged from the hospital on the fifteenth day, the incision having healed by primary union.

CASE 4. (Dr. Van Derwerker's Case) F. V., age 47, male, has pain in the left knee with a history of repeated "slipping out" sensation in which the knee gives way and he must massage the knee for some minutes, and then limp about for several hours afterward.

The duration of the condition is about fifteen years.

History. About fifteen years ago the patient was riding a mowing machine when some disorder in the machinery caused him to be thrown quite violently from the seat to the ground where he landed on his left knee. Following that injury he was laid up for several days, and was treated by a local doctor. He had swelling about the knee and "water" in the joint. Since that time he has had return attacks in the knee, has always spared that knee more than the other, and has had to wear a rubber elastic "knee cap" to prevent the "slipping out" sensation.

Examination made in September, 1920, showed the following:

The left knee was somewhat larger than the right. Angle of greatest extension 170, of flexion 100. The patella was free and moved easily. There was considerable tenderness at the inner side of the knee joint, over the inferior surface of the inner condyle and also in the region of the internal lateral ligament, but not enough to suggest a dislocated cartilage. Just beneath the quadriceps tendon and just above the patella at its outer side, was felt a small movable mass which could be pushed inward and outward, in the patellar pouch. This was identified by the patient as being the thing which "slipped out" and gave him so much discomfort when the knee was flexed and under tension. He was advised to have the foreign body removed and the knee joint explored.

In February, 1921, the patient was admitted to the Hospital for the Ruptured and Crippled and the left knee explored.

The usual Jones incision was made in the region of the left internal semilunar cartilage and the knee joint was opened and semilunar cartilage was found to be firmly attached and evidently not the cause of any trouble. The lower surface of the internal condyle was examined, with the tenderness on previous examination in mind, and the cartilage in this region was found to be reddened and granular, and there was a depression about the size of a finger nail on the joint surface which occurred to us as being probably the source of the loose body, which we removed after transfixing with a needle and making incision down to the patellar pouch. This loose body was irregularly shaped like an almond about 1¼ by 1 inch and was attached to the synovial membrane by a thin fibrous strand and had a shiny cartilage-like surface. The knee joint was closed and the patient remained in bed for 5 days, and was allowed to go home in a week. The specimen was retained by a patient.

Subsequent history. The patient has no more "slipping out" sensation and is able to go without the knee bandage. The leg can be fully extended and flexed to 80 degrees. There is still tenderness over the internal condyle and on rainy days the patient's knee aches, also when walking or working hard.

MYOSITIS OSSIFICANS

A Clinical and Radiological Study

By THOMAS P. NOBLE, M.D., F.R.C.S., Rochester, Minnesota
Section on Orthopedic Surgery, Mayo Clinic

MYOSITIS ossificans was first described nearly 200 years ago. Since that time many cases have been reported in the literature; and many cases must have been diagnosed and treated which have not been reported. A report of the group of 18 cases observed in the Mayo Clinic in the last 13 years may help to indicate the age incidence, sex, and the relative frequency with which it appears in various muscles.

The traumatic type of myositis ossificans is important because of its close similarity to sarcoma. The etiology and clinical manifestations of these two diseases have many points in common, and mistakes in diagnosis have doubtless been the cause of the loss of many limbs, myositis ossificans traumatica being mistaken for sarcoma. It is probable that the converse is also true, cases of sarcoma being diagnosed as myositis ossificans, and the disease becoming advanced with secondary growths before its true nature was discovered. The difficulties of diagnosis must often be considerable even to clinicians of great experience as shown by the discussion between Morley and Gould, published in the *British Medical Journal* following a paper by the latter on the treatment of sarcoma of bone by radium. The case described by Coley also gives an idea of the difficulties in diagnosis.

The great European war must have produced many cases of myositis ossificans. Those that have been described in the literature have clearly shown that it may occur after open injuries, whereas formerly it was ascribed to closed injuries; still more recently cases have been described in which no history of injury was obtainable.

DEFINITION

Under the term *myositis ossificans* are included several distinct pathological and clinical entities:

Fig. 1. Case 1. Myositis ossificans occurring in the flexor muscles of the forearm. No history of trauma. Contracture of the tendons of the ring and little fingers.

1. Myositis ossificans progressiva. This is a progressive disease coming on in early life, sometimes soon after birth, of unknown etiology, in which all the muscles of the body are slowly converted into osseous tissue.

2. Myositis ossificans circumscripta, generally known as the muscular osteomata, and appearing in sites of repeated slight injuries or irritations, such as "rider's bone."

3. There is a third form of the disease which is also localized to one site in the body, but is the result of a variety of etiological factors, the commonest of which is a single, severe closed trauma. It may be merely a contusion or a dislocation, but since the great European war it has been shown to follow tangential bullet wounds. Other forms develop after an abdominal operation, especially on the stomach. It is difficult to determine what bearing the gastric juice may have on the condition; in any case a bony or periosteal injury could not have taken place. Some of these cases have been complicated by septic infection, others have healed by first intention. Others are described in which a complete muscle has become ossified following a pyæmic abscess. There is still another form in which no history of injury can be obtained, and in which a complete muscle slowly becomes ossified; such a form is one of the most interesting and seems to bear some relationship to the generalized and progressive type of disease, and to be analogous to the generalized and localized forms of osteitis deformans. The third form of the disease only will be referred to in this paper.

THEORIES OF CAUSATION

Many theories have, from time to time, been put forward to explain the causation of myositis ossificans, but no one seems to offer an explanation satisfactory for all cases. The various theories are, briefly, as follows:

1. Diathesis. The patient possesses a peculiar diathesis, called by Virchow the "ossifying diathesis."

2. The escape of synovial fluid. Ewald suggested that the escape of synovial fluid from the knee or elbow afforded the necessary stimulus for the ossifying process.

3. The mechanical theory. A severe subcutaneous injury, usually a blow, may or may not produce a dislocation, but the muscle fibers are lacerated and the periosteum torn.

Fig. 2. Case 2. Myositis ossificans affecting the left thigh following closed trauma.

Fig. 3. Case 3. Myositis ossificans in the quadratus femoris following dislocation of the hip. Nine months after injury.

Fig. 4. Case 4. Myositis ossificans in muscles on the inner and anterior aspect of the humerus following puerperal septicæmia.

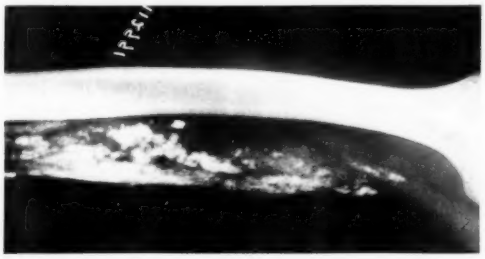


Fig. 5. Case 4. Myositis ossificans in the muscles on the inner and anterior aspect of the humerus following puerperal septicæmia.

The muscle fibers retract carrying with them the periosteum, or the periosteum plus a scale of bone. The osteoblasts, settled in a new and a suitable nidus, produce bone.

4. Metaplasia. The initial change is an interstitial myositis with a transformation into bone of intramuscular connective tissue. The growth is not derived from bone and any attachment to bone is secondary and accidental.

5. Tumor formation. This must of necessity be an innocent growth, as it shows no tendency to infiltrate tissues, or to metastasize. Coley has reported a case in which there was a malignant transformation and metastasis, but there was some doubt regarding the original nature of the case.

6. The organized blood clot is slowly transformed into cartilage, and then into bone.

7. Aberrant sesamoid bones.

On consideration of the anatomical disposition of the two most common sites, that is, the quadriceps and the brachialis anticus, we find that both these muscles take origin from extensive plane surfaces of bone; hence the periosteum is not so firmly attached and more readily gives rise to breaches of continuity, and the periosteum with its scale of bone can be readily drawn up into the overlying muscle.

A considerable amount of experimental work has been done on animals with regard to the production of myositis ossificans, and attempts to produce injuries to the periosteum have been made on the cadaver. Davis and Hummecut transplanted a scale of bone with the periosteum attached to the muscles and subcutaneous tissues of the rabbit; new bone was produced in each case, but the amount seems to have been disappointingly small, and in time this bone was absorbed. These authors conclude that periosteal flaps with bone shavings attached produce new bone. Berthier carried out similar experiments chiselling pieces of bone off the shaft and allowing the muscles to draw them away, but he found that the contusion was difficult to produce with a chisel, and the bone never grew much larger than the flap which was cut. Marcus carried out some experiments on the cadaver. He tried but failed to detach bone by pulling on the muscles; however, the conditions are not the same as in the living. Morley curetted the periosteum from the bone in rabbits and contused the muscles. He asserts that the same change took place as in human beings.

No one theory appears to explain all the types of myositis ossificans. Some appear to be entirely mechanical in origin, and one cannot but think that the ossifying diathesis of Virchow plays a part, in addition to injury, in the cases in which myositis ossificans develops in both quadriceps after comparatively minor trauma of a closed nature; the interval between the two traumas may be several months or a year. The mechanical theory appears to be borne out by a certain amount of experimental evidence and still more so by the cases following tangential gunshot wounds. This theory appears to give a satisfactory explanation of the cases following a closed tangential blow. The lacerated muscle fibers contract, carrying periosteum and osteogenetic cells with them into a nidus of lacerated muscle and blood clot, or from an area of bone denuded of its periosteum, and bone corpus-

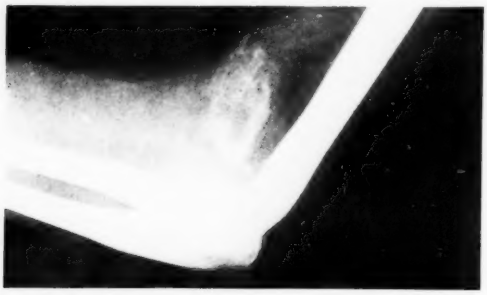


Fig. 6. Case 5. Myositis ossificans following posterior dislocation of the elbow. Four weeks after injury.

Fig. 7.

Fig. 8.

Fig. 7. Complete transition from bone to muscle. (A416126.)

Fig. 8. Section from center of the mass showing osteogenetic tissue with laminated layers indicative of pathologic bone formation. (A416126.)

cles pass out by ameboid movements into the blood clot. These bone-forming cells placed in a new nidus take on new life and produce new bone. The theory of metaplasia seems to offer a satisfactory explanation for another group of cases, especially those which follow a pyæmic abscess, an abdominal operation, or appear spontaneously without injury. The change set up is an interstitial myositis with the transformation into bone of the intermuscular connective tissue, the growth is not derived from bone, and any attachment to bone is secondary and accidental. The easiest transition would appear to take place in the abdominal wall, following abdominal operations, the lineæ transversæ which are the relics of abdominal ribs, passing back to their primitive state of osseous tissue.

MICROSCOPIC CHARACTERS

The microscopic characters distinctly favor the mechanical theory. The cells infiltrating the muscles are merely osteoblasts. They can be seen everywhere and in every shape and transition from the mature osteoblasts to the undifferentiated connective-tissue cell. The cartilage cells are really an intermediate stage. The presence of cartilage in the center of the bar of bone is explained by its lower vascularity.

SITES, AGE, AND SEX

Several authors during the last 15 years have recorded groups of cases, indicating the relative frequency of the various sites in which the disease occurs, and the age and sex of the patient. Jones and Morgan record 339 cases, partly their own and partly collected from the literature; in order of frequency they find the following muscles involved: brachialis anticus, quadriceps, adductor longus, and biceps. Schultz gives a record of 10 years' experience in the German army, and reports 233 cases, showing that the disease is more frequent than is generally believed, the quadriceps and brachialis anticus were the site of disease in all but 3 cases; 2 of these involved the masseter, and 1, the pectoralis major. Strauss records 127 cases chiefly in muscles of the arm; in order of frequency the muscles involved are brachialis anticus, quadriceps, adductors, gluteal, temporal, and thumb muscles. Most of the other series of cases are small in number and include a large variety of muscles. Ewald reports cases in the deltoid, triceps, biceps, adductor magnus, and subclavius, all following injuries. Horvath reports a case in which the disease developed in both iliac muscles following manipulation of a flexed and adducted hip joint. Lewis reports cases in which the condition occurred in the anterior abdominal wall following operation. Schartz observed the condition in the gluteal muscles following a cut from glass, Elmslie in the gluteal muscles following a metastatic abscess, and Whitelocke in the soleus.

The great bulk of the cases are in males and occur in early adult life, when one is more likely to be exposed to injury, although cases are recorded having occurred as early as at 5 years of age, and as late as 65 years.

Muscles affected in the 18 cases in this series are:

	CASES
Quadriceps	6
Brachialis anticus	5
Quadratus femoris	2
Sternomastoid and biceps	1
Tensor fascia femoris	1
Flexor muscles and forearm	1
Tibialis anticus	1
Coracobrachialis	1

Fifty per cent of the cases occurred between the ages of 15 and 25 years; the youngest patient was 12, and the oldest 52. Thirteen of the patients were males and five females. Operative interference was carried out in 7 of the 18 cases.

CLINICAL APPEARANCES

The quadriceps and the brachialis anticus are the two commonest sites of the condition. The condition in the quadriceps generally arises from a blow on the football field; the trauma is generally closed, and takes place tangential to the femur. Myositis ossificans in the brachialis anticus is generally the result of a posterior dislocation of the elbow, or an intra-articular fracture of that joint. After incurring an injury to the thigh on the football field, the patient is generally able to finish the game, but sometimes is compelled to leave the field. A swelling slowly forms at the site of injury; it looks like a hæmatoma, is not generally painful, but is tender to the touch, and causes considerable limitation of movement of the neighboring joints. The condition slowly improves for 10 or 15 days, then it commences to increase in size, pain develops, and the movements which were increasing in range, slowly begin to decrease; the swelling now becomes increasingly hard, and goes on to ossification. The diagnosis from the third week onward is made clear by X-ray.

The clinical picture may be divided into three stages (6): (1) the tissues are infiltrated with blood, (2) the swelling loses its elasticity and becomes indurated, and (3) the swelling assumes a bone-like consistency.

X-RAY APPEARANCE

In from 3 to 4 weeks the shadow is apparent by the X-rays, separated from the diaphysis of the bone by a zone of light. This light shadow is very constant, except where the callus is concave and encircles the bone. When the disease develops in the brachialis anticus following a posterior dislocation, the callus is frequently attached to the coronoid process and appears as a triangular or club-shaped process. The shadow is by no means a homogeneous one; light areas appear here and there. The light areas in the callus may indicate a cyst or cartilage. The picture is continually changing and the shadow gradually grows darker and more homogeneous. There is slow and steady increase in density until many months afterward, when ultimately the callus becomes attached to the bone, where probably in the first instance the periosteum became detached. The zone of light between the diaphysis and the callus does not necessarily mean that the callus is free; there may be a pedicle of spongy bone; a broad zone signifies the absence of such an attachment. If a complete muscle is involved, the shadow is at first mottled and later becomes homogeneous. Stripes and spots, and later lamellæ appear which correspond to the ossification of the muscle bundles or fascial layers.

DIFFERENTIAL DIAGNOSIS

The differential diagnosis applies particularly to the disease occurring in the quadriceps. Many conditions have been mistaken for myositis ossificans occurring in that situation, particularly sarcoma. These two diseases have many points in common, clinically, etiologically, and by X-ray. In both, there may be a history of trauma, generally closed trauma. The length of time between the receipt of the injury and the appearance of the tumor corresponds in cases of sarcoma and of myositis ossificans, the growth being rapid in both diseases. Before bone begins to form, that is, during the first 2 or 3 weeks, myositis ossificans cannot be distinguished from sarcoma, except by the microscope; later on, the diagnosis is easily made by X-ray.

Besides these points of similarity, however, the two diseases possess several points of dissimilarity. In myositis ossificans the growth usually ceases after a number of months, and absorption takes place to a certain extent.

In sarcoma, growth continues unrestricted. The position in relation to the shaft is helpful in differentiating the two conditions. Myositis ossificans is more likely to occur in the middle of the shaft, if in the thigh, or at least away from the epiphysis. In sarcoma, the swelling is more likely to be at, or near, the epiphysis. Myositis ossificans is uniformly hard on palpation. In sarcoma in the midst of the hard swelling there are some areas which are softer and more yielding to pressure. Pain is likely to be a feature in the early phases of myositis ossificans, whereas in sarcoma there is rarely any pain in the early stages. The disability in the neighboring joint is seldom noted in the early phases of myositis ossificans. By X-ray, the shaft of the bone is shown to be intact and the new bone is separated by a line of light, whereas in sarcoma the shaft of the bone is not intact.

Coley recorded the only case in the literature of myositis ossificans developing into sarcoma. There seems to have been doubt from the beginning as to the true nature of the condition, although it was confirmed by microscopic examination. The patient later developed sarcoma and died of metastatic infection. Coley concluded from this case that myositis ossificans will, under favorable conditions, develop into true sarcoma.

PROGNOSIS AND TREATMENT

It is impossible to predict that any injury will produce myositis ossificans, and the extent of the growth cannot be predicted with any degree of accuracy, although, doubtless, it has some relationship to the severity of the injury and the area of bone denuded of its periosteum. It is a comparatively rare condition, considering the frequency of posterior dislocation of the elbow and contusion of the thigh, which are its two commonest antecedents, although the X-rays show it to be much more common in minor degrees than is appreciated. The natural tendency is toward cessation of growth after some weeks, and a variable degree of reabsorption. In fact, in many cases, perfect function has been restored. The degree of disability depends on the mechanical embarrassment of the muscles and the neighboring joint. In some cases whole muscles may be transformed into bone, and cause a greater or lesser degree of disability and deformity, depending on their site.

In the past, many lines of treatment have been advocated. These differ widely. Morley advocates simple excision of the bony mass with grafting of fascia over the denuded area. Lapointe says extirpation of the mass, 6 to 8 weeks after the trauma, is the method of choice. Shere advocates immediate aspiration and prolonged drainage until the tissues feel normal. He considers this condition to be a forerunner of sarcoma. Maddren says that unless serious disability exists and persists, unimproved by active and passive exercises, surgery is contra-indicated. The treatment of this condition naturally falls into two distinct stages: (1) the treatment of the two commoner disabilities which may produce myositis ossificans, namely, posterior dislocation of the elbow and closed injuries of the thigh, and (2) treatment of the complication when it has arisen.

Treatment of the disabilities leading to myositis ossificans. Posterior dislocation of the elbow should be reduced carefully and gently, under anæsthesia, then fixed for 2 or 3 weeks in a completely flexed position with the forearm supinated, the palm of the hand toward the shoulder. At the end of 2 weeks if the tenderness on manipulation of the joint is gone, the sling can be gradually lengthened, and the patient move his arm back to the normal position. If it gets stiff in a less flexed position and he is unable to flex the elbow fully, that is an indication that we are proceeding too quickly, the osteogenetic tissue is being irritated, and further rest in the flexed position is necessary. This irritation is shown by the production of local heat and by the muscles being on guard. The arm should be put up in the acutely flexed position for another week, then treatment renewed with voluntary movements and the gentlest of massage. In this way the process of repair is carried on with the minimum of trauma to the fibrous and osseous tissues.

Closed injuries to the front of the thigh should be treated by complete rest until the acute symptoms have passed. Contusions are so common in this area, that many pa-

tients receive no treatment whatever until myositis ossificans has developed.

Treatment of the actual condition. Myositis ossificans generally appears about the third week, earlier if injudicious movements have been carried out. A definite mass in the muscle may be felt at this time, and a distinct shadow can be seen by the X-ray. Two facts to keep in mind in the treatment of this condition are: (1) simple excision in the early phases is invariably followed by recurrence, and (2) the disability due to interference with locomotion may ultimately give way, under physiotherapeutic treatment, and perfect restoration of function take place, although months or years may be required. The treatment may be divided into three stages. It is summarized by Makins as follows:

1. During the period in which myositis ossificans is developing, the treatment is complete rest.

2. When the process has ceased and begun to consolidate, massage and exercise is called for.

3. When the process has come to a standstill for 6 months and there is functional disability sufficient to warrant surgical interference, or when a large vessel or nerve is interfered with, operative treatment is indicated. The operation consists simply of the removal of bone through an appropriate incision.

ABRIDGED RECORDS OF FIVE CASES SELECTED FROM THE EIGHTEEN OBSERVED IN THE MAYO CLINIC FROM 1910 TO 1923

CASE 1. (A419118.) A man, age 25 years, came to the Clinic because of pain and swelling in the right arm. When he was about 10 years old, he had noticed that the right arm and shoulder were small and weaker than the left. At the age of 12 he noticed a swelling in the right forearm, which was especially painful if he bumped it. At the age of 15, he began to notice a slight stiffness in the right elbow. During the last few years the forearm had ached, even when undisturbed. There were no sensory disturbances, although the right arm became cold from time to time.

On examination, a tumor involving the flexor muscles on the inner aspect of the forearm was found. The tendons of the ring and little fingers were somewhat contracted. The forearm could not be completely extended. The Wassermann reaction was negative. The X-ray showed a dense tumor with multiple areas of calcification in the upper and inner aspect of the forearm.

At operation the tumor was found to involve the flexor muscles of the forearm, chiefly the flexor carpi ulnaris; practically the entire belly of this muscle was taken up with the tumor. The tumor when sectioned was found to consist of fibrous tissue, cavernous spaces filled with blood, and multiple scattered calcareous deposits.

The pathological diagnosis was myositis ossificans. Ten months later the condition was much the same; there was still contracture of the ring and little fingers, and several hard and tender areas were present in the muscle belly (Fig. 1).

CASE 2. (A119994.) A boy, age 17 years, was hurt while playing football 2 months before coming to the Clinic, but kept on playing. He did not know the exact nature of the blow. Swelling appeared in the thigh almost immediately, then seemed to decrease in size for a time, but recently had increased in size, particularly during the last week. There had been considerable pain at first, but there was very little when he came to the Clinic.

On examination, diffuse swelling was evident over the lower half of the left thigh, with some effusion into the knee joint. There was no redness or tenderness, and only very slight local heat. The left thigh measured 2.5 centimeters more in circumference than the right. The patient was unable completely to straighten the knee, but it could be passively straightened. The X-ray revealed a well developed subperiosteal hæmatoma in the lower third of the left femur.

After exploration, the tumor was removed, and a rubber dam drain inserted. The left knee was aspirated. The pathological report was myositis ossificans. The patient's recovery was uninterrupted (Fig. 2).

CASE 3. (A43004.) A man, age 50, was run over by a team 9 months before coming to the Clinic. The accident resulted in dislocation of the hip, which was set under an anæsthetic. After 7 days he walked, dragging the leg. Since then he has always limped.

On examination there was complete fixation of the hip joint in 30 degrees flexion with no real or apparent shortening. The X-ray showed myositis ossificans in the quadratus femoris (Fig. 3).

CASE 4. (A112991.) A woman, age 21 years, had had puerperal septicæmia 2 years before coming to the Clinic. Soon afterward, she had noticed lumps in her neck; these had remained more or less stationary for some time, and then had increased rapidly in size.

On examination, a chain of small, hard lumps like calcified glands were found, running down to the right under the clavicle, and there were calcifying nodules along the biceps in the left arm. Spasm of the left sternomastoid muscle was also noted. The X-ray revealed calcified cervical glands and marked calcification of the muscles around the lower and anterior aspect of the humerus.

At operation, a calcifying mass of the right cervical region, probably myositis ossificans, was found lying in the sternomastoid region. It appeared to lie on each side of the sternomastoid muscle without actually involving it. This mass was removed, and the pathological report was myositis ossificans. Three years later, recurrence of the disease in the neck could not be detected, but the condition was spreading in the arm (Figs. 4 and 5).

CASE 5. (A452238.) A woman, age 34 years, had been thrown from a rig 4 weeks before coming to the Clinic, and had struck on the elbow, which was dislocated backward. It had been replaced under an anæsthetic 10 hours after the injury. Since then, the movement of the elbow had been extremely limited. There was no pain and no paralysis of the muscles. The patient had had chiropractic treatment, which increased the disability.

On examination, a mass in the front of the elbow was clearly felt to the inner side of the median line of the arm. The mass was 6 centimeters long, and 1 centimeter wide. The range of movement was 45 degrees flexion and 125 degrees extension. The X-ray disclosed myositis ossificans in the brachialis anticus (Figs. 6, 7, and 8).

SUMMARY

Myositis ossificans is a comparatively rare disease. It follows both open and closed trauma, occurs after acute infections, and spontaneously when there has been no history of infection or trauma.

Myositis ossificans occurring in the quadriceps, is often confused with sarcoma, and differential diagnosis is important.

The commonest sites of myositis ossificans are the quadriceps and the brachialis anticus. The treatment in the early stages is rest and fixation. If operative procedures are carried out in the early stages, recurrence is practically certain. Operation is only to be considered after 6 months, and if distinct functional disability exists.

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MENINGOCEREBRAL ADHESIONS

A Histological Study of the Results of Cerebral Incision and Cranioplasty

By WILDER G. PENFIELD, M.D., New York

From the Department of Surgery, College of Physicians and Surgeons, Columbia University, and the Pathological Laboratory of the Presbyterian Hospital

THE desire to cure or prevent traumatic epilepsy has led neurological surgeons to employ a bewildering variety of implants into dural and cranial defects. Drevermann (4) has summarized these efforts at some length. Widespread discussion of this problem particularly since the beginning of the war in 1914 has demonstrated great vagueness of thought as regards its underlying pathology. Experimental investigations of the viability of various transplants are plentiful, but careful histological studies are rare and studies of the process of "wound healing" in the brain still rarer. The following communication deals particularly with the mechanism of adhesions, changes in different types of neuroglia-cells being ignored for the present.

TECHNIQUE

One set of experiments was carried out on a series of dogs in the winter of 1922–23 approximately as follows: The lateral aspect of the cerebral cortex was exposed, with aseptic precautions, by turning down a large bone flap and excising the underlying dura. A similar exposure was then made of the opposite cerebral cortex. On the cortex of one side were placed a square of celluloid and a square of celloidin[1] side by side, held in place by a silk suture fastened to the margins of the dura. A puncture wound was made into the brain between the squares and in some cases wounds were made so as to be covered by the squares.

In the cortex of the opposite cerebral hemisphere a wound of loss of substance was made with a scalpel and squares of fat, excised dura and fascia placed, in order, over the wound and held there as though on a clothesline by a silk suture fastened to dura in front and back. A cuff of celloidin was folded about the margin of excised dura on one side or the other. Both bone flaps were then replaced and each fixed to the skull by a silver wire bone suture, or silk sutures in the periosteum. In two of the ten animals in this series, decompression openings only were made, leaving the defect in the bone.

In the following year these experiments were supplemented by a second series of dogs. Either a bone flap was made on one side and decompression done on the other or a bilateral decompression was done. Stab wounds and implantations of strips of dura were made into the brain, or grosser wounds of the cortex were made and covered with sheets of fascia or fascia and fat which were sutured into the dural defect. Thus on most of the twenty animals used two separate operations were done each of which served as a control for the other.

One animal died with an operative infection and one on the second day from postoperative hæmorrhage. In one there was leakage of cerebrospinal fluid and this one was sacrificed early. The remaining 17 animals recovered perfectly after operation and were killed at different intervals up to 7 months by anæsthesia and perfusion of the carotid with 10 per cent formalin in normal saline solution.

The method of postmortem examination is of importance. If the skull cap be removed in the usual way or direct dissection be attempted, it is well-nigh impossible not to break adhesions between the brain and its covering. After the above fixation a saw cut was made parallel to the tentorium and just above it, and another slanting back and downward through the anterior part of the frontal lobes. When these two cuts met a wedge-shaped piece of skull and brain could be removed containing the field of both operations intact. In the case of a decompression a deep incision was then carried around the rim of the bone defect so that a cylinder containing brain membranes and muscle could be removed without disturbing the relations of these structures. The exact extent of ad-

[1] Pyroxylodion, Dupont.

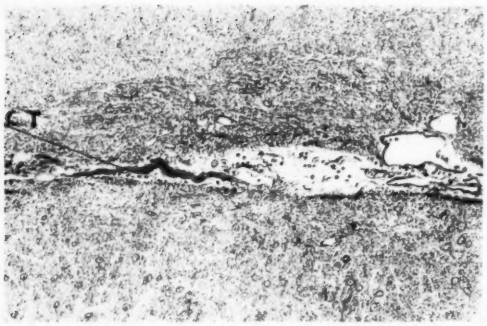

Fig. 1. Experiment 10, Mallory's neuroglia stain. Longitudinal section of the tract of a ventricular needle passed into the ventricle 7 months previously. *c.t.*, Connective tissue in the tract. Empty spaces and rarefied tissue lined by a condensation of glia fibrils.

hesions could thus be seen in the gross and their nature studied in microscopic sections. In the case of bone flaps the brain was usually dissected away from the under surface of the cranial vault until the bone flap was approached. Then by gentle retraction the degree of adhesion and the nature of membranes between bone and brain could be made out and secured for section.

The blocks of brain with undisturbed coverings were embedded and cut in celloidin for the

Fig. 3. Higher power photomicrograph of field drawn in Figure 2 to show the connective-tissue core and surrounding glia condensation.

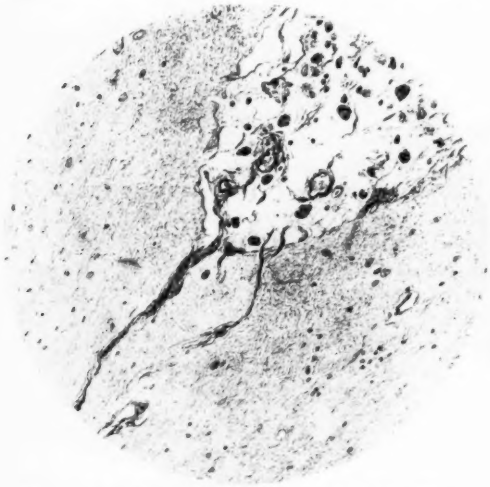

Fig. 2. Experiment 10, Hæmatoxylin and Van Gieson. Bottom of laceration made with scalpel 7 months previously. Loose net-work of connective tissue in the tract and entering the brain.

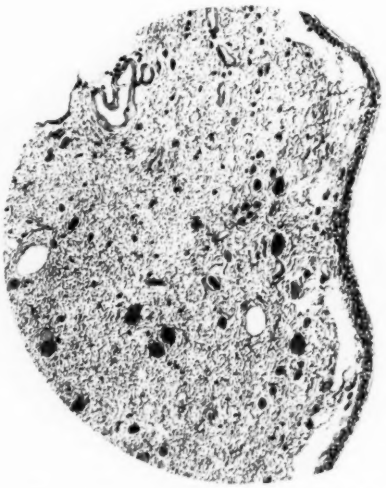

Fig. 4. Case 9. Mallory's neuroglia stain. Lining of empty tract left by passage of small ventricular needle 7 months before. Membrane of glia fibrils.

Fig. 5. Experiment 7. Hæmatoxylin and Van Gieson. The newly formed dura, *d*, 69 days after simple decompression, is free from arachnoid, *a*, except at one point.

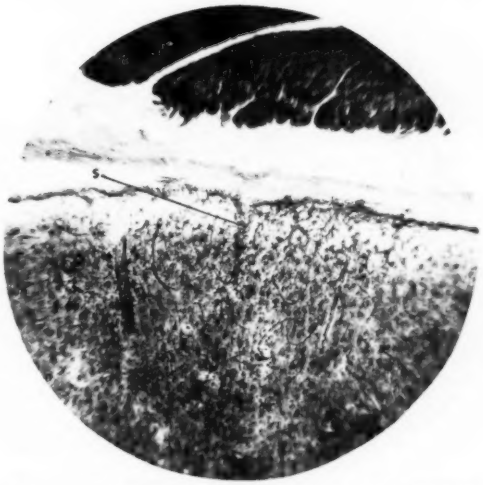

Fig. 7. Experiment 13. Cajal's neuroglia method. Photomicrograph showing superficial gliosis and adhesion about small stabs, *s*.

most part. These sections were stained by Mallory's Phosphotungstic acid hæmatoxylin method for neuroglia, Nissl's method for nerve cells and Van Gieson and Mallory's methods for connective tissue. It was also found to be possible to cut good sized sections after freezing the properly fixed blocks. Thus blocks were fixed in a solution of 15 per cent neutralized formalin and 2 per cent ammonium bromide. After the length of fixation called for by the different methods sections were cut from each block and the block returned to the fixative. Thus sections of the same block were stained by a number of different methods:

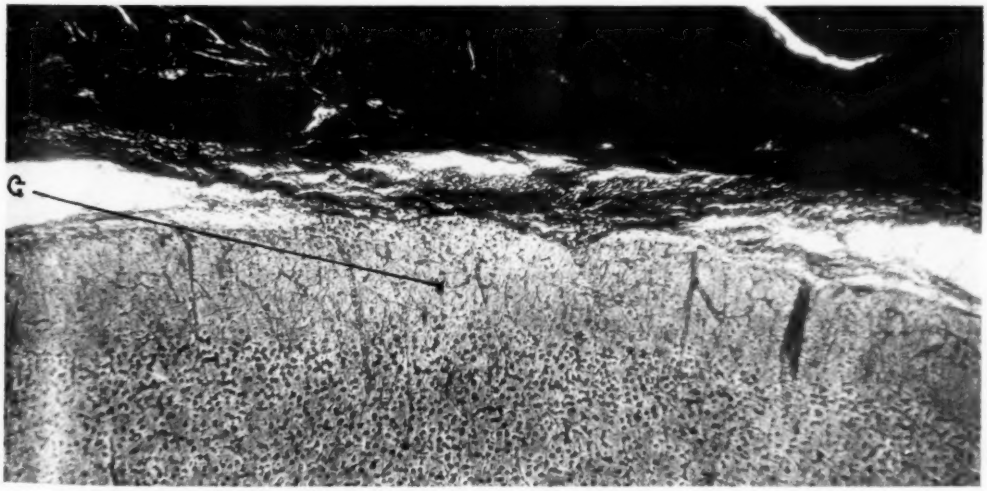

Fig. 6. Experiment 13. Achucarro's method, fourth variant. Photomicrograph showing conditions 92 days after decompression with removal of dura. Circumscribed adhesion to superficial gliosis, *g*.

Fig. 8. Experiment 13. High power photomicrograph of same specimen as shown in Figure 7. Neuroglia black. Dura unstained.

Cajal's gold-sublimate method (1) for fibrous and protoplasmic neuroglia, Rio Hortega's fourth variant of Achucarro's tannin method for neuroglia (3), Rio Hortega's silver carbonate methods (9, 10) for microglia and for fibrous and protoplasmic glia. It was possible to stain sections from these blocks by the hæmatoxylin and Van Gieson method and specific methods for fat as well.

BRAIN WOUNDS

Brain wounds do not heal in the sense of reproduction of parenchyma but certain progressive changes are observed. Six days after the removal with a scalpel of a small area of cerebral cortex, fibroblasts and a few new vessels were to be seen in the blood clot between the replaced bone flap and injured area of brain. There were also present numerous large round cells two to three times the diameter of a red blood cell (granulo-adipose cells or Gitterzellen). The cytoplasm of these cells contains many small round fat droplets as shown by specific fat stains. Occasionally the vacuoles are large and then the nucleus which is typically near the cell membrane is apt to be flattened against it. The cells may be seen at times on the outer surface of blood vessel walls laden with fat droplets. Nineteen days after a similar wound this process of phagocytosis was going on actively and the nuclei consistently flattened against the cell periphery. These phagocytes are in reality microglia cells in an amœboid form as demonstrated by the Spanish investigator, Rio-Hortega. After several months some wounds, even deep ones as stab wounds, contained none of these phagocytic cells, if they may be called so, while in other cases they continued to be plentiful even as long as 7 months after a simple incision.

Fig. 9. Experiment 7. Hæmatoxylin and Van Gieson. Low power photomicrograph showing the connective-tissue envelope which formed about a piece of celluloid placed between brain and temporal muscle 69 days before autopsy. The piece of celluloid has been removed from the slit.

In addition to the formation over the surface of the brain of a new dura by fibroblastic proliferation, fibroblasts were early found in brain wounds themselves forming a loose network at the site of injury from which the brain elements were disappearing (Fig. 1). These connective tissue strands may be so sparsely scattered as to seem to be suspended in fluid (Fig. 2). Phagocytes may be present and a few vessels. At the surface such a network is continuous with the overlying dura. In Case 18, stabs were made with a cannula, the size of a small lumbar puncture needle, into the parietal lobe and the bone flap replaced. Four months after operation, on lifting the skull from the brain, thread-like cores about 1 centimeter in length attached to the bone were withdrawn from the holes. These fibrous threads (Fig. 3) seem to have a loose structure

when seen through the microscope, yet they are possessed of considerable tensile strength and, thanks to their firm attachment to the overlying fibrous meninx, must be capable of a considerable pull upon the brain tissue about the tract (Fig. 2).

If a narrow strip of dura is freed, leaving its base attached, and if the free end is then buried in brain, the condition at autopsy is found to be much the same, except that the dura strip retains its compact formation unchanged and completely fills the tract. Into rarefied areas along the tract a loose network of fibroblasts may be seen to pass from the implant.

As early as the sixth week after an incision, it is found to be bounded by a loosely interlacing layer of neuroglia fibrils. In Cases 9 and 10, 7 months after incision, there appeared a denser brush of neuroglia fibrils surrounding the areas of loss of substance. The deeper wounds were sometimes found to be represented by empty tunnels. In some cases the neuroglia fibrils formed a sort of superficial limiting membrane to the tunnels (Fig. 4); in others the membrane was more diffuse (Fig. 3). The cellular structure of the glia varied considerably. The layer of fibrils about the tracts of puncture wounds contained very few nuclei. Beneath this in many areas could be seen marked neuroglia hypertrophy and hyperplasia.

By means of differential stains for connective tissue and neuroglia, it was shown that some of the wound tracts were free of connective tissue and were in fact empty, while others contained loosely branching connective tissue which interlaced with a loose brushwork of glia fibrils.

Changes in nerve cells were absent even close to a brain wound. In some cases, however, evidences suggesting a destructive process were present even as late as the seventh month. Phagocytes were present in the neuroglia brushwork and adjacent nerve cells showed some tendency to chromatolysis. In experiment 11, five weeks after operation, Nissl stains showed next to each stab wound the usual narrow zone of tissue which stained faintly. In some sections the cytoplasm of neurones near this area stained faintly although the position of the nuclei was normal. In other sections there was frank chromatolysis, some cells being swollen, with nuclei at the periphery and cytoplasm opaque.

Fig. 10. Experiment 10. Hæmatoxylin and Van Gieson. Membrane, *m*, which formed between celloidin and brain wound. Connective-tissue strands, *c.t.*, enter rarefied areas of brain and phagocytes, *ph*, are still present 7 months after operation.

A deep brain wound does not heal in the sense of healing elsewhere in the body. The neurones disappear about the injured area. There is apparently a long continued phagocytosis. Apparent condensation of neuroglia fibrils may take place and a cavity may result. Along the tract of injury connective tissue usually extends from the surface where it is continuous with the connective tissue covering the brain.

DURA REPAIR AND SUPERFICIAL ADHESIONS

Regrowth of a membrane resembling dura beneath a decompression opening has been demonstrated in recent experiments by Sayad and Harvey (11). As those authors point out, this has long been recognized by neurological

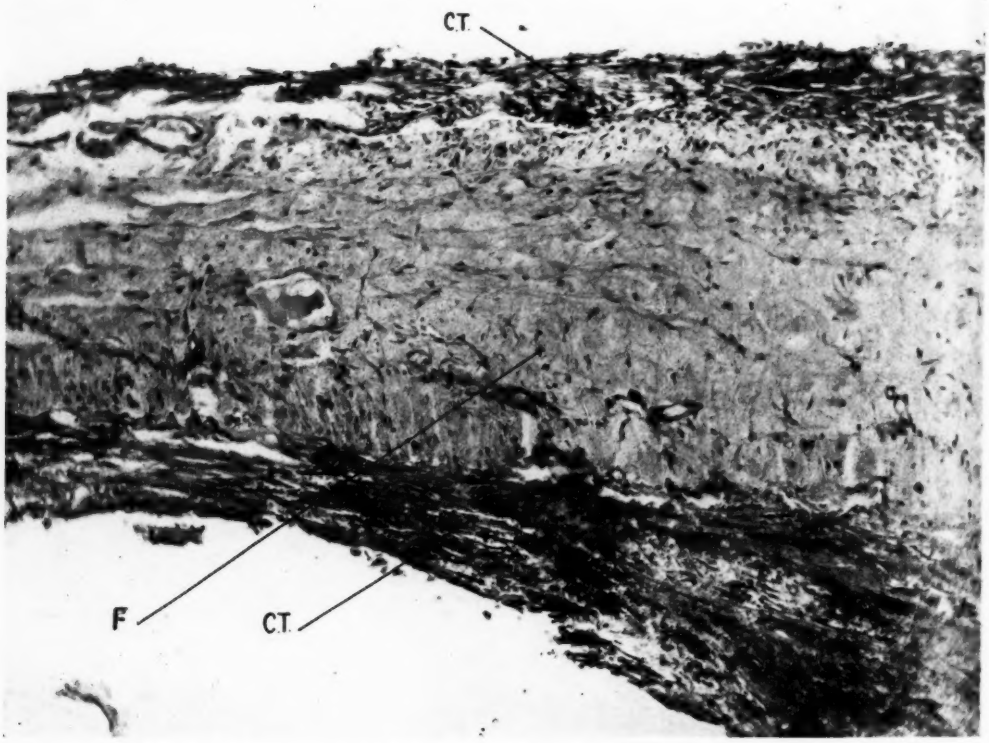

Fig. 11. Experiment 1. Hæmatoxylin and Van Gieson. Transplant of fascia lata, *f*, to surface of brain beneath bone flap. Six days after operation fibroblastic layers, *c.t.*, already present on both sides.

surgeons. The growth of the membrane is rapid. It is not adherent to the underlying arachnoid (Fig. 5) and the cells with which it lines the sub-dural space resemble the arachnoid cells which line that cavity.

When a bone-flap operation is done the conditions are somewhat different. In the first place vascularization must come from the side or beneath, not from the covering. Also the factor of movement is largely eliminated. A membrane does form, adherent to the bone flap and free from uninjured brain. But it is much thinner than that which forms beneath the scalp and temporal muscle. The sheet of tissue varies a good deal being thicker over a laceration and much thicker over a foreign body.

If there has been injury to the brain, adhesions form, no matter what the covering. If the injury is a gross one causing brain destruction the adhesions are composed of connective tissue strands entering the injured areas as described elsewhere in this communication. Adhesions however may occur in the vicinity of larger injuries or at the site of a very small superficial injury. The adhesion shown in Figure 6 corresponds to a circumscribed superficial gliosis (Fig. 6, G). There is no evidence of actual wound. Figure 7 shows a localized adhesion in the same case. Here a glia increase can be seen to center about a small stab and about this area the dura is adherent. Figure 8 shows the nature of the same adhesion more highly magnified. The connective tissue is unstained. The silver impregnation demonstrates the entrance of the neuroglia fibrils into the overlying connective tissue and throws light on the mechanism of adhesion.

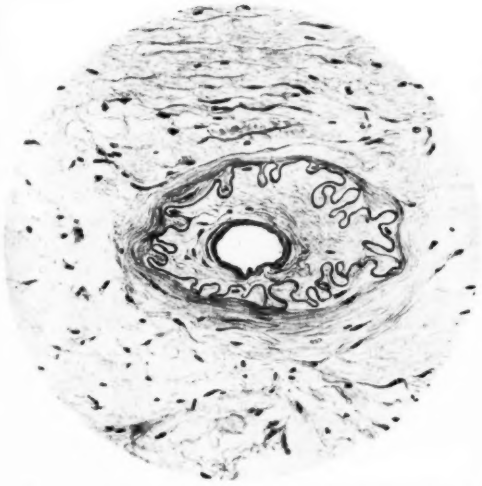

Fig. 12. Experiment 8. Canalization of thrombosed artery in fascia which had been transplanted to the surface of the brain four months before autopsy.

THE BRAIN UNDER FOREIGN BODIES

When a sheet of celluloid or celloidin[1] was placed over the intact surface of the cerebral cortex no changes were observed in the underlying neurones nor was there any evidence of a diffuse alteration in the neuroglia. In areas where the foreign body pressed upon brain as at an edge there resulted some thickening of the superficial layer of glia.

There was a response to the presence of the foreign body on the surface of the brain however. It was rapid and intense, but mesodermal in character. There formed a dense covering of connective tissue on all sides which, at the end of four weeks offered firm resistance to section and later seemed as hard as cartilage (Fig. 9). The connective tissue sheet opposed to each surface of celluloid was pearly white and glistening, the external sheet being adherent to overlying bone, in the case of a bone flap, or to muscle in the case of a decompression. The inner sheet seems to have left the arachnoid membrane intact although the pia-arachnoid spaces may at times have appeared to be obliterated by pressure.

[1]This has been shown by W. C. Clarke (2) to be among the least irritating of foreign bodies.

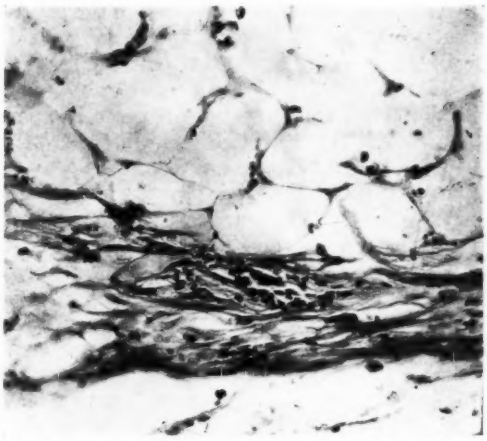

Fig. 13. Experiment 1. Hæmatoxylin and Van Gieson. Growth of fibroblasts beneath fat 6 days after it had been transplanted to surface of brain.

When a thin sheet of celluloid or celloidin is placed over a fresh brain laceration there forms rapidly, as described above, a dense connective tissue covering. The under covering (Fig. 10) is continuous with the connective tissue strands which pass downward into the laceration to interlace eventually with the neuroglia brushwork. The presence of the non-absorbable foreign body over the wound does not seem to alter conditions except that two dense sheets of connective tissue like a bursal cavity are substituted for the one layer of such tissue which would otherwise overlie the wound and be adherent to it and the coverings above. In the former case adhesion is direct between brain scar and skull or scalp. In the second a cavity is interposed. The reaction to celluloid seems to be about the same as to celloidin.

THE BRAIN UNDER TRANSPLANTS

When fascia lata, fat or an excised piece of dura is transplanted to form the covering over a brain laceration there is rapid growth of new fibroblasts in the blood clot about the transplant, and down toward the laceration. There is, as a result, adhesion to the brain scar and to the overlying structure. A dense layer of connective tissue results, and in this layer can be recognized the fibres of the dura or fascia

transplant. External and internal to the transplant new parallel fibroblastic layers are laid down tangential to the brain surface (Fig. 11). The fascia lived, to judge from the staining reaction of its cells, and in several cases "canalized" arteries were found in the transplant (Fig. 12).

In cases where the fascia was sutured to the edges of the dural defect, the reaction was the same, the transplant became adherent to overlying covering and was densely fixed to any underlying brain scar. Such a transplant certainly does not prevent adhesions although in the absence of brain injury it may not form them.

When fat was used as a transplant or a fat-fascia sheet was sutured into the gap with fat next to the brain as is so ably recommended by Drevermann (4) and by many others, the result was the same. There rapidly formed new connective tissue all about the fat (Fig. 13). The amount of fat seemed to decrease and, in some cases of long standing, none could be found remaining.

SUMMARY

After a simple brain wound active phagocytosis continues over a long period and with it progressive disappearance of brain structure. Neurones adjacent to such an area of rarefaction may show chromatolysis as late as seven months after operation. Between normal brain structure and such rarefaction is found a brush work of neuroglia cells and sometimes a limiting layer of neuroglia fibrils. In the cavity is found a loose connective tissue network.

Deep adhesions are composed of connective tissue threads attached to dura, or its substitute, and to the glia brushwork at the bottom of the brain wound. Superficial adhesions result from slight injury and extend some little distance over the surface of the brain from the point injured. These adhesions are composed of an interlacement of connective tissue fibrils from the dura, with the fibrils of a superficial gliosis.

The thickness of the new or adventitious dura, formed after removal of the old, varies according to the available blood supply. Movement and foreign bodies are also factors to be considered. The dura is thick after a decompression operation and thin beneath a bone flap. It is thicker over a brain laceration.

Placement of the least irritating foreign bodies, as celloidin, on the surface of the brain causes a very thick, hard connective tissue envelope to form all about it. The results are the same even when there is no wound of brain and when the foreign body lies beneath a relatively non-vascular bone flap. The layers of this envelope form a bursa-like cavity preventing direct adhesion to the scalp or skull. Adhesion between brain wound and lower layer of the envelope forms, of course, as well as adhesion between upper layer and skull or scalp.

Transplantation of various tissues to the surface of the brain is followed by rapid growth of a layer of fibroblasts above and beneath the transplant. Such procedures are useless if their purpose is to prevent adhesions, for fibroblasts grow wherever the conditions are suitable as do organisms in a contaminated wound. Thus the transplant is incorporated in the adhesion of brain to its covering.

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FIBROSARCOMA OF THE TRANSVERSE COLON

By FRED W. RANKIN, M.D., F.A.C.S., and J. C. CRAGER, M.D., Lexington, Kentucky
From the Lexington Clinic

THE diagnosis of intestinal sarcoma of whatever variety is rarely definitely made but usually is discovered at autopsy or during an operative procedure for some other condition. The rarity of such a condition is well illustrated by the fact that out of a series of over 13,000 autopsies performed at Prague, over a period of 15 years, only 13 cases of intestinal sarcoma were found. By the location in the intestine found in this series it is obvious that, with the exception of the rectum, the large bowel is exceedingly rarely invaded. The small bowel too is not the site of frequent occurrence, but here the picture, which is usually that of lymphosarcoma, is much more frequently observed. Lymphosarcoma of the small bowel has been reported in the literature about 250 times and quite recently we have had 2 patients with this condition, in one of whom the malignant process had invaded the ileocæcal valve and the mucosa of the caput cæcum itself. The locations in the intestines in order of frequency are: ileum, jejunum, ileocæcal valve and duodenojejunal angle, rectum, sigmoid, cæcum, hepatic flexure, transverse colon, and splenic flexure.

It will be observed that the splenic flexure is rarely the site of malignant invasion by sarcoma and indeed carcinomatous invasion of this segment of the colon is less frequently found than in any other division. It is inaccessible to surgery, which makes this fact more readily appreciated although its lymphatic supply which according to Madelung is scarce, renders it a less liable site for recurrences.

Histologically lymphosarcoma originating in the lymphatics is most frequently found in the small bowel. This tumor begins in the submucous lymphatic glands, grows along the long axis of the bowel wall, and early involves the muscular layers, thus permitting a dilatation of the bowel lumen because of the muscular paralysis.

Keen notes that intestinal dilatation is a feature of especial interest though not a constant phenomenon in lymphosarcoma occurring in the small intestine. In the large intestine, the type of sarcoma most frequently found in the rectum, which is the favorite site of this type of pathological growth, is melanotic, and here as elsewhere, pigmented malignant tumors metastasize early and are unfavorable in their prognosis. Primary pigmented tumors anywhere in the intestines are rare. Vandervert and Kellert have observed that they are most often secondary deposits. According to Ewing, the great majority of sarcomata in any division of the bowel, large or small, are of lymphomatous type, although a considerable number are of the fibroblastic spindle cell type, located in the muscular layer external to an intact mucosa.

The clinical course of patients, in whom intestinal sarcoma is found, offers little that may be considered of real diagnostic aid as to their pre-operative nature. It is that of almost all chronic gastro-intestinal diseases to which, in the later stages, are added the characteristic features of malignant cachexia. The symptoms differ from those caused by carcinoma in corresponding locations in few details. When it occurs early, obstruction is the most frequent symptom probably which causes patients with gastro-intestinal malignancy to seek aid, and it occurs more slowly and with less frequency in sarcoma than in carcinoma. This is explained by the type of the growth, its usual point of beginning and the absence of necessary mechanics to produce intestinal obstruction in the early stage. Sarcoma of any type tends to produce either elongated masses parallel to the intestinal segments or spherical growths with dilatation. When obstruction occurs, it is not usually due to a constricting action of a cylinder growth, as is the case in carcinoma, but to one or more of three conditions, namely: invagination; di-

rect pressure from enlarged lymphatic glands; or intussusception. Invagination is a rare cause of obstruction. Pressure from the enlarged lymphatic glands usually is compensated for by a dilatation of the proximal segment. Intussusception is found more often than would be suspected. In 1914 Speese reported 74 cases of resection of the small bowel for sarcoma, in 14 of which the complication of intussusception was noted. This is approximately 19 per cent and differs somewhat from Cassemeyer's statistics, which show this complication in 26 out of 284 cases or slightly over 9 per cent. The mechanism of this frequently is a polypoid growth in the lumen of the intestines, which is carried along by the normal peristalsis or it may be due to the normal gut being telescoped into the dilated sarcoma portion. It has long been an axiom that sarcoma occurs more frequently in young individuals than carcinoma and Keen warns that in intestinal tumors in patients under 15 years of age one should always think of sarcoma, over 40 years of age, of carcinoma. In Libman's series the age incidence ranged from 5 days to 70 years. Albion collected 10 cases in children. Comparing this total with the entire result of intestinal sarcoma that Goldstein was able to find in the literature, it is readily seen that nearly 7 per cent occur in children.

This percentage however, can be considerably augmented if the number of cases occurring in young adults is added to it. Another point of differentiation which has been emphasized by some authors, is the presence of a large rapidly growing intestinal tumor or several tumors in the intestine, which is considered most indicative of the sarcomatous type. In reviewing the reported cases, it is found that in 100 instances every segment of the gastro-intestinal tract was found involved.

Intestinal tuberculosis, particularly of the hyperplastic type, which occurs so frequently in young adults, must always be differentiated from malignancy. Occurring as it most frequently does, close to the ileocæcal valve, and presenting early many of the symptoms of cachexia, it is not without some difficulty that its true nature is demonstrated. In neither of the conditions is the X-ray of so much value, as in the more frequently ulcerating carcinomatous growths. Malignant tumors of the colon, particularly in its transverse segment, have a tendency to metastasize, not only into the neighboring lymph glands, but also into the adjacent omentum and occasionally the primary growths develop in the omentum itself. Aimes, in a review of omental tumors, found 53 primary sarcomata of this origin. The symptomatology of the tumor itself obviously is the same whether primary or secondary and the principal observations brought out with reference to omental sarcoma are that they occur as a rule in young subjects; that the mass is unusually large; that the tumors are vascular, fragile, and hæmorrhagic—operation usually is difficult; that adhesions are formed early; that cystic degeneration is a frequent accompaniment (cystic degeneration is found so frequently, indeed, that occasionally sarcomata are described as myxomatous growths or some other type of cyst); that omental sarcomata frequently are pedunculated and have been found in hernial sacs; that ascites is present usually in about one case in four and usually, but not always, hæmorrhagic; and that the primary sarcomata nearly always are found to be single, the secondary ones are usually multiple.

While all the cellular varieties have been encountered, the spindle-cell growths constitute about 50 per cent of the total number. In the early formation of the growths, either primary or secondary, no symptoms are produced, but once the tumor becomes widespread in the omentum, grave disorders arrive readily. Gastric disturbances then are nearly constant and ascites usually is abundant. Partial intestinal obstruction, œdema of the lower extremities, pain and other signs of compression occur in rapid sequence. Dyspnœa ensues as the mass becomes progressively larger and death occurs either from pressure or from general sarcomatosis. The early diagnosis of the condition is difficult, but a flat palpable tumor at the level of the umbilicus, or more frequently a little to the left is a helpful finding. The mass usually is felt just beneath the abdominal wall. Before

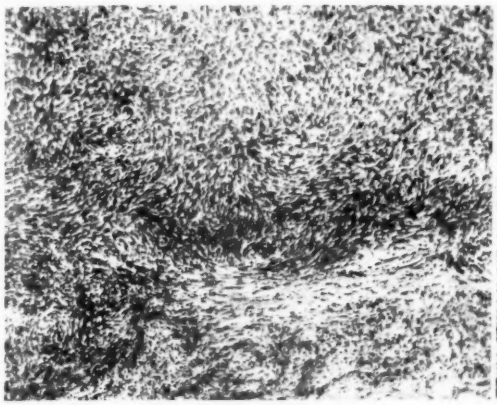

Fig. 1 (left). Low power photomicrograph showing that the fibrosarcomatous nature of the growth in this section is typical and deserves no detailed description of its histological nature. The purpose for reproducing it is to show the rather distinct boundary remaining peripheral to the mucosa, illustrating the tendency of the tumor to grow away from the lumen of the bowel rather than into it. Free passageway through the colon was thus maintained, accounting for the absence of evidence of obstruction and for the lack of bleeding.

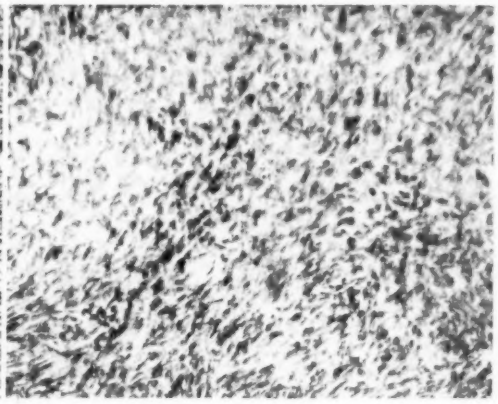

Fig. 2. High power photomicrograph of a section through the main tumor mass showing the type of cells constituting the growth. These sections were taken from the fibrosarcoma occupying the colon and omentum.

adhesions are formed, it is freely movable from below upward, moderately from side to side and least of all from above downward. In the beginning it moves slightly with respiration. In our own case the tumor in the omentum was unquestionably secondary but the adhesions which took place early between the omentum and a fibroid which it overlay and between the omentum and the peritoneum, while characteristic of this type of growth, did not lead us to the suspected diagnosis. There was no œdema of the extremities in our case nor was there any constipation, a fact which is explained by the absence of encroachment on the lumen of the bowel by the primary growth and also by the fact that the omental tumor, which extended from the dilated transverse colon to the fibroid below, acted as a bridge because of its adhesion to the abdominal wall and thus removed pressure from the remainder of the intestinal tract.

TREATMENT

In the case appended the diagnosis of a large uterine fibroid with some pelvic inflammatory disease complicating it, caused us to undertake the operation. There had been no symptoms referable to the gastro-intestinal tract which led us in any way to suspect malignancy. It was noted that the fibroid apparently was attached to the anterior abdominal wall, but the pelvic inflammation was felt to be a satisfactory explanation of this fact. It was not until a large pedunculated fibroid, the size of a 6 months' pregnancy, had been removed that the omental tumor was found and exploration for the primary growth revealed it in the transverse colon. The removal of this segment of the large bowel despite its mobility and its ease of access is not so successfully carried out as that of some of its fellow divisions for several reasons. The blood supply, which comes from the middle colic vessel, is plentiful and is distributed through fairly constant arcs and is so large that accidental injury to the main vessel, during the course of a surgical procedure upon adjacent viscera, is followed by gangrene in a very small percentage of cases. The protection which is afforded by the wrapping of the omentum around the colon in these accidental injuries, may explain this in a large measure but in dealing with malignancy and resection of the colon, one must sacrifice the omentum as well for fear of implantations. To re-establish the lumen of the bowel, either by axial or lateral

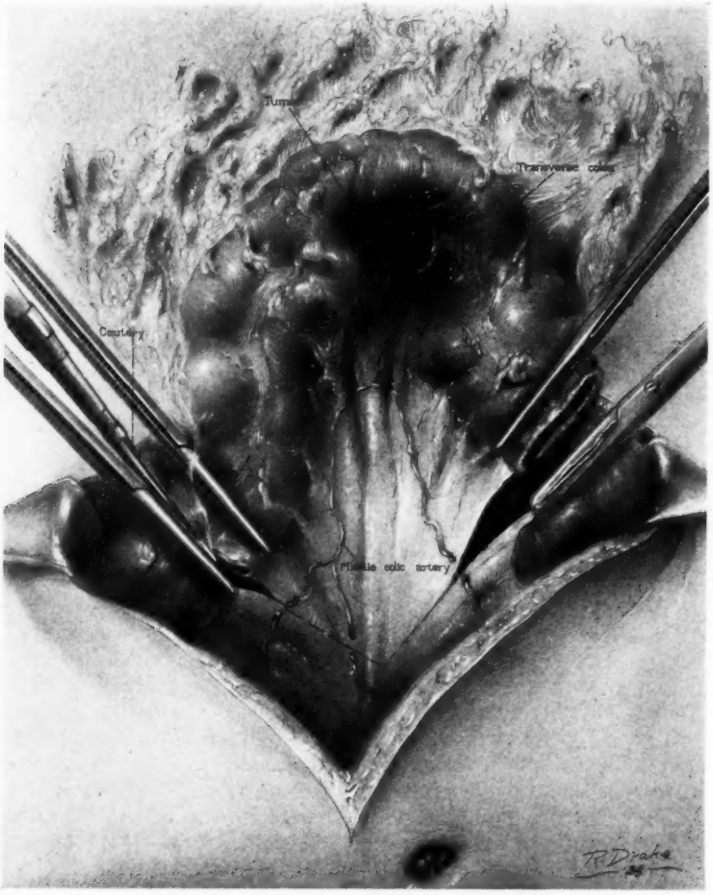

Fig. 3. Transverse colon reflected upward; with clamps in place. Artery cautery being used on the colon.

anastomosis in the one stage is not without considerable liability to leakage. The mobilization of the transverse colon is a simple technical procedure because it is swung from two points of suspension, namely, the less mobile hepatic and splenic flexures which are readily explored. The lymphatic supply of this colonic division is particularly large however, there being a chain of lymphatics, not only in the mesentery of the omentum, but also in the gastrocolic omentum and directly into the great omentum. This same chain of glands between the stomach and transverse colon, which is so readily invaded by malignancy from the stomach itself, is early the site of metastasis in colonic cancer. The glands in the great omentum, while early invaded are more readily and easily removed with that organ itself. A complete operation which will insure a reasonable percentage of 5 year cures and at the same time be well within the mortality limits, which are considered justifiable, must take into consideration a gland dissection. The restoration of the continuity of the bowel, while easy of accomplishment by end-to-end anastomosis in most cases, is followed by a high mortality because of the leakage of the suture

Fig. 4. Stumps of transverse colon brought out of upper end of wound with an ileostomy of the lower end.

line due to faulty nutrition. Lateral anastomosis is usually not feasible because of lack of bowel substance and in the hands of many operators has been abandoned for various other reasons. The Mikulicz procedure is satisfactory from the standpoint of immediate mortality, and yet the slow convalescence from this operation, coupled with not infrequent recurrences both in the abdominal wall and the lumen of the bowel, precludes its acceptance as the ideal procedure. Unless one ligates the blood supply and thus removes the gland bearing area in the mesocolon in carrying out a Mikulicz operation, the chances of recurrence later are greatly increased. On the other hand, if one does ligate the blood supply the local condition which confronts him at the end of 72 hours is not always acceptable. Bowel which is brought out of the abdominal cavity after having its blood supply ligated, soon has a tendency to become thickened, œdematous, and, in many instances, necrotic. The omentum must be resected if the transverse colon is brought out in this type of operation. Just epiploic appendages and fat tags in other segments must be sacrificed to prevent the entire extraperitoneal mass from becoming foul smelling and necrotic. In some patients who are anæmic and whose tissues have a retarded power of repair, the cutting off of the extra-abdominal loop of bowel is followed occasionally by a peritonitis.

The mortality then in all types of operation which formerly was as high as 50 per cent, but which under modern technique has been reduced to approximately 10 per cent, will not be found to be decreased with a Mikulicz operation unless some other procedure in addition is adopted. We have tried the application of two stages of this procedure in one, doing the operation between clamps, removing the bowel segment with a cautery and leaving the bowel at the site of operation obstructed for a number of days. Supplementing this type of retention with an ileostomy about 16 inches from the ileocæcal coil, is a valuable adjunct toward reducing the untoward postoperative symptoms by draining the toxic products of the small bowel. The steps of the operation are simple and quickly accomplished. The mobilization of the transverse colon is made by first selecting two points, one on either side, at which the bowel is to be divided later. As much of the omentum as possible and generally all of it, if it is invaded,

should be sacrificed. In dividing the omentum care should be taken that small bites are caught in the artery forceps and that numerous points of ligation are made. This obviates the danger of subsequent necrosis and embolism. The colon should be freed from the omental attachment to the stomach in the same way. The blood supply in the transverse mesocolon is now ligated close to the root of the mesentery, every precaution being exercised to preserve the arcs supplying the ends of the bowel to be left. The bowel with the omentum should be removed with the cautery. This has the advantage of a complete gland dissection and obviates the danger of contamination at the time of primary operation. The heavy clamps which hold the end of the bowel are held at the upper end of the wound and a few interrupted catgut stitches join the peritoneal coats of the two arms of the colon precisely as in the original Mikulicz procedure. An ileostomy is made after the Witzel technique, and the tube permitted to emerge from the lower angle of the wound or from a stab wound in the flank. One or two sutures are sufficient to hold the bowel attached to the peritoneum. The clamps should be left on at least 72 hours and better 96 hours. On their removal necrosis will be found to have taken place on the line of division and frequently slightly below it, but not into the peritoneal cavity. There is no danger of necrosis far back along the bowel walls because one can be sure not to sacrifice blood supply too far back to permit healthy bowel being in approximation with the peritoneum. The other steps of the operation can be carried out as in the original Mikulicz procedure, but I believe may be undertaken earlier if there are no untoward symptoms. This method seems to have the distinct advantage of permitting a gland dissection and, at the same time, an aseptic removal of the bowel without danger of sloughing at the divided ends and the production of a subsequent peritonitis. It is a graded procedure however which requires time for its completion. This should not be considered a formidable disadvantage, however, if the extirpation of the malignancy can be done in a radical way with a lowered mortality.

THE TIME ELEMENT

The time element within very elastic limits is a negligible feature in the treatment of malignancy if the end-result is satisfactory. On the other hand graded operations, which necessitate a long convalescence and which ultimately fail to prolong life, are not satisfactory.

The appended case illustrates largely the technical points mentioned and is of interest because of the extreme rarity of the pathological type of the tumor, as well as its anatomical location.

M. B., age 41; married; occupation, laundry maid.

Patient entered hospital 4 years previously with same complaint as at present (except vomiting), but had not been operated upon.

She complained chiefly of tumor in the abdomen with pain. She had vomited frequently for 2 weeks previous to admission. One sister had epilepsy, family history otherwise negative. Patient's general health had been good until she noticed the appearance of the abdominal tumor 4 years ago. She had had the usual childhood diseases with uneventful recoveries, i.e. measles, mumps, and whooping cough. Malaria and pneumonia in late childhood, no recurrences since. She has had frequent headaches, occasional vertigo of a transient nature, epistaxis for past 4 years once each week—at times bled so much that she was forced to bed on account of weakness. Mouth and throat examination negative. Cardio-respiratory system negative. Gastro-intestinal tract negative, until 2 weeks ago. Since that time, whenever patient ate or drank anything she would be liable to a "hot feeling in stomach" and would then be nauseated and vomit. After vomiting she would feel perfectly well. No blood was found in vomitus. The bowels moved regularly and purgatives were seldom used. No malæna. Patient urinated once each night, and suffered moderate frequency and burning on urinating in day. Menstruation began at age of 14 and was normal until the patient was 37 years old at which time it stopped spontaneously. Almost 4 years later, 7 months before last admission, patient bled from vagina profusely for 3 days. This bleeding ceased without treatment, and there have been no recurrences since. Patient married at age of 15, and has had one pregnancy with normal delivery. She has had no miscarriages. She has had a slight leucorrhœal discharge for past 5 years. Examination of nervous system is negative except that patient has had a feeling of uneasiness concerning her condition for the past 6 months. Patient's best weight was 175 pounds. She says that she has lost considerable weight in the past year. She did not know how much and her appearance was not at all cachectic.

About 4 years ago patient felt a mass in her lower abdomen. It seemed to change its position when she would sit down and rise, and it frequently caused a bearing down sensation. This mass has enlarged gradually since that time. Shortly after its appearance her menses stopped. Patient has been able to work constantly until 3 weeks before admission at which time "the heaviness in her abdomen wore her out." As stated above, she vomited frequently during the 2 weeks before entering the hospital.

Physical examination and pre-operative diagnosis. Patient is a well developed and nourished negro female, 41 years old, with clear mind, normal skin, and no œdema. The head is negative except for moderate oral sepsis. The neck is negative. The chest is symmetrical, showing slight depressions in both infraclavicular regions, no lagging on respiration. Voice sounds and breath sounds are normal; no râles heard. The heart is normal in size and position; sounds are distinct, no murmurs. The abdomen bulges as in pregnancy. The tumor mass is smooth except to the left of the umbilicus, where it feels as if it were adherent to the abdominal wall. Dullness extends from pubis to three finger breadths below xyphoid cartilage and well to both sides. No masses could be felt that did not seem continuous with the main tumor. No areas of tenderness could be made out. The extremities are normal, with no œdema. The vaginal outlet is marital in type. Bartholin's and Skene's glands are negative. The perineal floor is in good condition. The cervix is firm and a pinkish secretion exudes from the external os. Bimanual examination reveals a mass extending up from the uterus and continuous with it. It is apparently the same mass as was made out on examination of the abdomen.

Rectal examination is negative except for the same mass.

Laboratory data: Urine is amber color, turbid; specific gravity 1,024; albumin and sugar, negative; acetone, negative. Microscopic examination shows a few epithelial and pus cells; no casts. Blood count shows white blood cells, 7,400; red blood cells, 4,200,000; hæmoglobin, 77 per cent.

Pre-operative diagnosis: Fibromyoma of uterus with adhesions from pelvic peritonitis.

Operation and findings. A mid-line incision was made. The peritoneum was found adherent to a large tumor. The peritoneal cavity was entered with difficulty. The tumor mass consisted of a large pelvic growth over which was adherent the great omentum which also contained multiple tumors of various sizes, having a dark red, meaty appearance. The omentum, which was everywhere injected with large, thin walled blood vessels was separated from the pelvic tumor. This was a pedunculated fibroid about the size of a 5 months' pregnancy and was attached to the fundus of the uterus a little to the right of the mid-line. It was removed by dividing the stalk between clamps. The uterus appeared normal, adnexa normal. The omentum with its tumors was then separated from the abdominal wall from below upward. In the upper abdomen a malignant tumor was encountered involving the middle third of the transverse colon. The patient was in good condition so that immediate resection was decided on. Clamps were left on the two ends of the bowel after sterilizing the cut lines with a hot iron. These ends were then brought out on the abdominal wall and the wound closed around them. This completed the first two stages of the Mikulicz operation. Before closing the abdominal incision an ileostomy tube was inserted close to the ileo-cæcal valve and brought out at the lower end of the wound.

The specimen removed consists of (1) the tumor removed from the uterus, a reddish gray, boggy muscular mass, almost spherical in outline, measuring 18 by 15 by 14 centimeters. The cut surface is pale yellowish gray with projecting masses varying from 2 cm. to 10 cm. in diameter. Other portions contained cysts averaging about 30 millimeters in diameter, containing a brownish gray fluid. (2) The large intestines are 18 centimeters in length, 4 centimeters across lumen, wall averaging 2 centimeters in thickness. It is reddish gray and contains firm masses varying from 10 to 40 millimeters in diameter which tend to encircle the entire lumen of the bowel. Cut surface through the masses reveals in some a semisolid fluid resembling a recent blood clot. The lumen of the bowel is larger than normal. (3) The omentum, 14 by 10 by 8 centimeters, contains a mass 6 centimeters in diameter in the center of the specimen. The cut surface presents a pale gray to yellowish gray, striated appearance. Much blood flows from the cut surface. Other masses 40 by 74 by 10 millimeters to 30 by 12 by 8 millimeters are found in omentum detached from, but similar to, above.

Microscopic diagnosis: (1) leiomyoma (pedunculated tumor removed from uterus); (2) and (3) fibrosarcoma of colon and omentum. A typical section from the last two is shown in illustration.

Postoperative convalescence. At the end of 96 hours the clamps were removed from the ends of the bowel. During this time the patient had not vomited and had not complained of abdominal discomfort. She had been kept under the influence of a narcotic, and fluids had been administered to her subcutaneously in the amount of 4,000 to 5,000 cubic centimeters every 24 hours. The condition was good. Heavy clamps were put into the lumen of the bowel and the spur cut out between the two segments, the operation being completed according to the usual Mikulicz procedure.

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DEPARTMENT OF TECHNIQUE

CANCER OF THE PROSTATE TREATED BY PERINEAL PROSTATOMY WITH THERMO-ELECTRIC COAGULATION

By B. C. CORBUS, M.D., F.A.C.S., and V. J. O'CONOR, M.D., Chicago

CANCER of the prostate is a fairly common disease and according to statistics occurs in from 15.5 per cent (Mayo Clinic) to 21 per cent (H. H. Young) of all cases in which obstruction occurs at the bladder neck.

As physicians become better trained and more skilled in urological diagnosis, it is highly probable that this serious affliction will be diagnosed earlier and in turn receive more rational treatment. It is not our purpose to enter into controversy with those who have had more experience in the various methods of treating this almost incurable disease, but rather to present a method for eradicating the malignancy without destroying the anatomical relations between the cancer and the prostatic capsule.

ANATOMICAL CONSIDERATIONS

According to Quinby, the apex of the prostate is supported by the deep layer of the triangular ligament. On each side is found the so-called lateral aponeurosis of the prostate. This runs from the descending rami of the pubis backward to join the rectum; and by it, the prostate is separated from the median margins of the levator ani muscle. It is closely applied to the sides of the gland and is united to it by the cellular tissue containing the vesical plexus of veins.

Behind the prostate, separating it and the seminal vesicles from the rectum, there is a transverse aponeurosis, known commonly as the fascia of Denonvillier. This layer is attached below and anteriorly to the apex of the prostate and triangular ligament and united above to the peritoneum, which descends between the bladder and the rectum. This last union is as marked as though there existed continuity of tissue and explains the constancy of the rectovesical cul-de-sac (Douglas' fossa). On each side this fascia is attached to the lateral aponeurosis described above. By its posterior surface it is but loosely attached to the seminal vesicles and to the true capsule of the prostate gland. The texture of this membranous layer is said to resemble that of the dartos. All these surrounding prostatic fasciæ make up the prostatic bed and these serve to control the direction and spread, not only of suppuration but also of malignancy in this area. Besides these aponeuroses described above, the prostate has a true capsule of its own which sends prolongations between the glandular lobes.

From the pioneer work of Lowsley, we are informed that cancer of the prostate develops primarily in the posterior lobe and when the lateral and median lobes are involved, this occurs secondarily from an extension of the process in the posterior lobe.

According to Young, "carcinoma of the prostate develops many times where hypertrophy is absent in both median and lateral lobes, the growth following planes of least resistance continues upward beneath the trigone toward the seminal vesicles and does not easily break through the capsules which surround the lateral and median lobe."

The mucosa and submucosa of both urethra and bladder are very resistant to invasion; and the constriction in the prostatic urethra often encountered during examination is due primarily to the crowding of the cancerous tissue up against the urethra and not to direct extension of the growth.

Cancer of the prostate may be of slow growth and remain for a long period well confined within the capsule of the prostate. Several years may undoubtedly elapse before periprostatic structures, seminal vesicles, and trigone are greatly involved. Intravesical tumor growth is extremely rare and occurs only very late in the disease and even then in a small percentage of all cases.

From the best authorities it is generally understood that the disease apparently remains well encapsulated for a fairly long period. Unfortunately, on account of its obscure position and often indefinable symptoms, its diagnosis is lamentably delayed.

From the foregoing and from a careful review of the anatomy of the prostate, we must look upon the prostatic capsules as anatomical barriers against the spread of the disease anteriorly and laterally. Since the rectum is so easily separated from the dense fascia which locks the cancer securely in its bed, it seems that the most rational method of attack is by the way of the perineum, for with proper exposure the cancerous tissue is brought directly beneath the finger without disturbing or in any way spreading the smoldering malignancy.

SYMPTOMS AND DIAGNOSIS

The symptomatology of cancer of the prostate is almost identical with that of benign hypertrophy.

Pain in the penis and perineum may be the first symptom noted but as a rule this is associated with frequency of urination and difficulty of urination, often accompanied with more or less urgency.

As the prostatic urethra does not as a rule become involved in the cancerous process, hæmaturia is not a necessary cardinal symptom unless associated with benign hypertrophy.

Too little attention is given to the symptom pain. It may be vague and very indefinite, in the back or referred to the sciatic notch, testicle, inguinal region, thighs, or legs. In arriving at a diagnosis every referred symptom should be carefully noted and regarded with suspicion. These are the cases which so frequently go without positive diagnosis for a long time and in many instances are subjected to futile manipulative therapy before the correct diagnosis is made.

Rectal examination. It is only by careful routine rectal examination that the diagnosis of early carcinomatous involvement of the prostate can be diagnosed; whereas it helps us comparatively little in the benign hypertrophy, it usually establishes the diagnosis in malignant disease of the prostate.

There is nothing so characteristic as the "stony hard" feeling so easily palpated by rectal examination. The involved portions of the gland are usually firmly fixed due to periprostatic inflammation. The cancer area is as a rule rough and nodular and can be sharply demarcated from the surrounding healthy tissue.

In passing a catheter or cystoscope one is often impressed with a tightness in the posterior urethra. This constriction may be so narrow that the passage of any diagnostic instrument is not possible until the prostatic urethra has been dilated. No examination should be completed without a satisfactory cystoscopic examination and while the cystoscope is *in situ* the gland should be thoroughly examined *per rectum* as it is only by this method that careful and complete findings are possible.

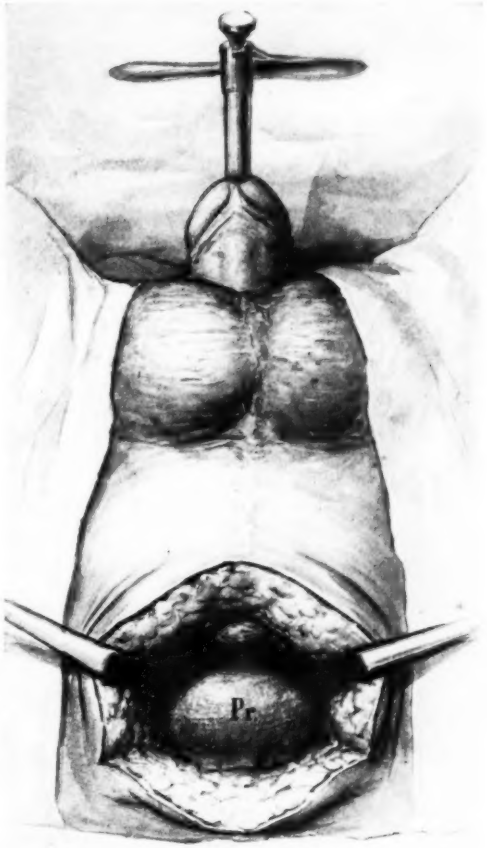

Fig. 1. Perineal exposure of the prostate after the method of Young. By passing the prostatic retractor through the urethra, opening the membranous urethra is avoided, and the danger of cutting into cancerous tissue is minimized.

OPERATIVE TECHNIQUE

The technique as devised by one of us (B. C. Corbus) is as follows: When there are symptoms of vesical obstruction with urea nitrogen retention due either to cancer of the prostate alone or to an associated benign hypertrophy, a suprapubic cystotomy should be performed and the bladder put at rest until the patient is in the best possible condition for operation.

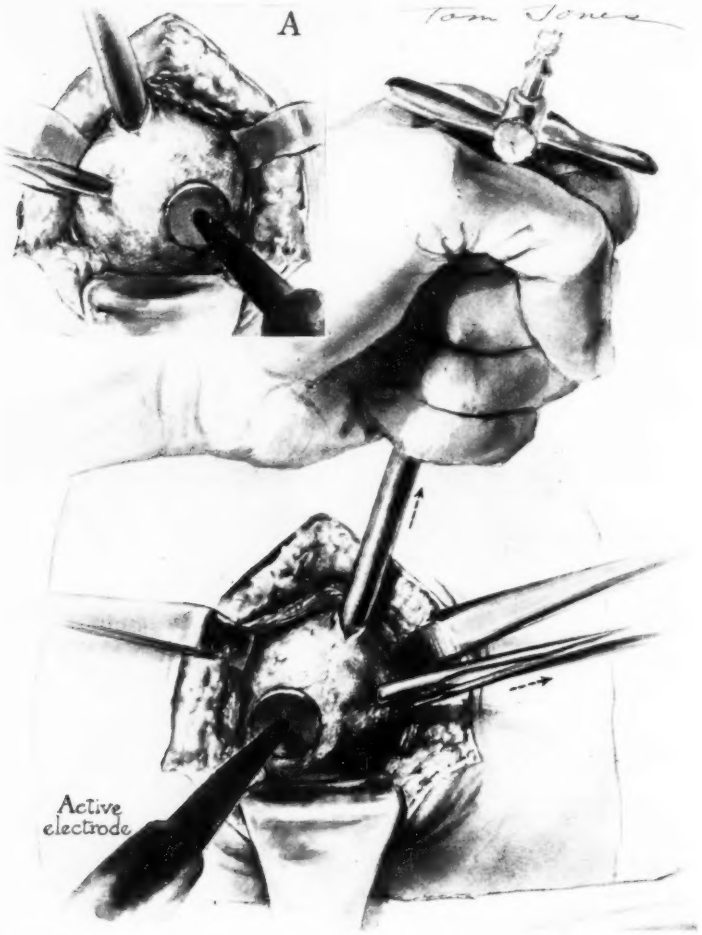

Fig. 2. Method of coagulating cancer of the posterior lobe. The flat disk electrode is in direct contact with the fascia of Denonvillier. By pulling the retractor to the right and left, the whole cancer area can be brought in contact with the flat disk electrode.

When simple hypertrophy accompanies the malignancy in the posterior lobe no attempt should be made at the time of coagulation of the cancerous growth to disturb the benign adenoma. We must be sure that the cancer cells are all destroyed before we remove the obstruction, lest we hasten metastases, the one thing we wish to avoid in the destruction of all malignancies.

PERINEAL PROSTATOMY WITH THERMO-ELECTRIC COAGULATION

Place the inactive electrode over the symphysis pubis with an intervening pad moistened well with hypertonic salt solution. Equip the active electrode with a flat disk (0.5 centimeter in diameter).

After the prostatic bed has been exposed sufficiently to permit easy access to all of the cancerous growth, the biopsy trocar or the "tissue taker" is next inserted into the growth and a piece taken for microscopical diagnosis. Immediately following this procedure the location of the puncture is thoroughly coagulated. This coagulation is then continued not only over all the area known to be involved in the malignancy but also to regions where there may be any possibility of involvement. If the growth extends upward toward the

Fig. 3. Method of passing the diathermy needle into the cancerous prostatic lobe. The method is identical with the application of radium as suggested by Young.

vesicle on either side, the prostate may be pulled aside with a tenaculum and the disk electrode pushed to immediate contact with the growth. When this is completed the needle electrode is substituted for the disk, as this permits a still deeper carrying of heat into the diseased vesicle and, with the distal finger inserted into the rectum as a guide, its direction is more accurately controlled so that any danger of perforating the rectal wall is avoided.

Thermo-electric coagulation of the cancer in the posterior lobe should be done slowly and carefully. In order to keep the rectal wall from burning while using the flat disk electrode, sponges moistened with hypertonic salt solution should be placed immediately outside of the area to be coagulated. By placing the inactive electrode over the suprapubic region, there is a direct path of heat transfusion which greatly facilitates the destruction of the growth.

If there is no benign hypertrophy complicating the cancerous growth an opening is made in the membranous urethra and a catheter is inserted into the bladder for drainage. Otherwise the drainage is continued from the suprapubic opening. The wound is next packed with strips of

gauze and the skin is closed as in perineal prostatectomy. Drainage may be removed in 24 to 48 hours.

POSTOPERATIVE CARE

Postoperative care is the same as that after perineal prostatectomy.

As previously stated when benign hypertrophy complicates the involvement in the posterior lobe, several months should elapse before an attempt is made to remove the adenomatous tissue. However, this should only be attempted after thorough roentgenological data shows no evidence of metastasis and likewise no evidence of local recurrence.

It must be remembered that the resulting sclerosis following the diathermy is even more dense and uniform than that following X-ray or radium, and resulting contracture of the internal urethral orifice is inevitable if there has been extensive coagulation.

When sclerosis has occurred we have employed linear cauterization (actual cautery) of the orifice through a suprapubic cystotomy. Following this the remaining portions of the obstructing lobes are slowly coagulated by diathermy. The frequent passage of urethral sounds assists in establishing rapid functional recovery.

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THE REDUCTION AND CONTROL OF UNMANAGEABLE FRACTURES BY MEANS OF A METAL PRY PIN[1]

By J. S. WELCH, M.D., F.A.C.S., Lincoln, Nebraska

IN the care of fractures, the reduction and retention of fragments is a problem of paramount importance. The mechanical task of approximating in fair apposition the fragment ends and so holding them long enough for a retaining callus to form, is often most difficult. Such problems have drawn upon the ingenuity of surgeons of all time and as a result an endless number of splints, traction and counter traction devices, mechanical braces and open operations have originated. In recent years, especially since the world war, certain concerted action to standardize the treatment of fractures has been undertaken and not without definite progress. Other things being equal, the more simple the device or operative procedure, the more satisfactory the results, because its accomplishments are possible in the hands of the largest number of surgeons and practitioners. But, it must not only be simple, it must also be safe. It must be mechanically correct. There must be the minimum chance of injury to blood vessels and other soft tissues. The risk of infection must be reduced to a minimum. Delayed risk due to buried wires, plates, screws, nails, etc., often requiring extensive operative procedure for removal, must be considered.

It was with the idea of better meeting such indications in unmanageable fracture, that the writer devised a so-called "pry pin" method of reduction and retention, some years ago. This method was then recommended to the profession and the brief description published in the *Journal of the American Medical Association*, March 20, 1920. Recently my attention has been called to the fact that Dr. Hugh Owen Thomas of Liverpool advocated some 50 years ago the use of this principle to reduce obstinate cases of backward dislocation of the thumb. The X-ray was not then available and no mention was made of its assistance. Moreover, he did not refer to incorporating the pry pin in the cast for retention purposes, a feature of great value in some cases. The lever principle he did use in the reduction of compound fractures, but simple fractures were rarely compounded by operation in those days. The features herein recommended, therefore, are new so far as the writer is aware.

During these years I have continued to use this method in a limited number of fracture cases, as have some of my colleagues in a more extensive experience, and we believe that the results warrant a more general acquaintance and application of the method.

THE FUNDAMENTAL PRINCIPLES

The fundamental principles underlying the method are few and relatively simple.

1. A small blunt steel pin is used as a lever between fragments. One bone end serves as the fulcrum to pry the other into apposition.

[1] Read before Sectional Meeting of Clinical Congress of American College of Surgeons, Omaha, Nebraska, February 19, 1924.

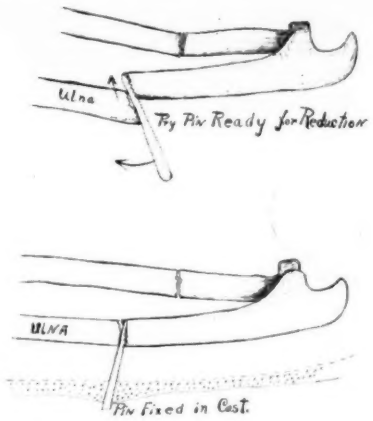


Fig. 1. Diagrammatic representation of principles involved in reduction and retention of fragments. Note toothed edge of pin, sometimes helpful in retaining contact with fragment. To remove such a pin, rotate 90 degrees and withdraw same as ordinary pin.

2. The pry pin is guided or directed into position and correct apposition of fragments is judged by aid of the fluoroscope.

3. Ordinary surgical asepsis is practiced, and since the skin opening is reduced to a single puncture wound, the risk is practically nil.

4. Ten days to 2 weeks will suffice in most cases to develop callus sufficient to retain reduced fragments held in a satisfactory cast. Then by simple extraction of the pry pin all further risk from buried mechanical retention devices, ends. In many cases the pry pin can be withdrawn at once if the fragment ends are so irregular as to retain their reduced position.

5. The character of pin varies with the thickness of the extremity, size of bone, and strength of muscles. It should be rigid but with bending properties rather than breaking, when extreme force is applied. Special irregularities of its surfaces where contact with ends of bony fragments is made, may assist in retaining approximation. (Ordinary threads cut on a tapering long shafted screw may be of assistance.)

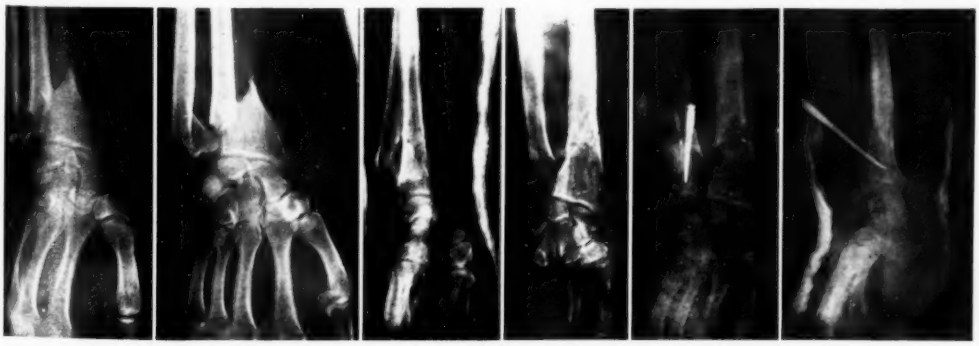
We have now tried this method with marked success in a moderate number of different cases in which repeated efforts to reduce or to reduce and retain had failed. These failures were not alone in the hands of the enthusiastic devisor of the method, but other colleagues of experience had also failed. To date my experience and that of Dr. J. E. M. Thomson of Lincoln, Nebraska (mentioned by consent) include fractures of the radius, ulna, tibia, fibula, femur, humerus, clavicle and metatarsals.

Table I will give in abbreviated form the detail considered essential.

It will be noted from this table that there have been no complications of note, no infection, no pressure necrosis, and that the convalescence time is no more than that of like fractures requiring only simple standard methods for satisfactory management.

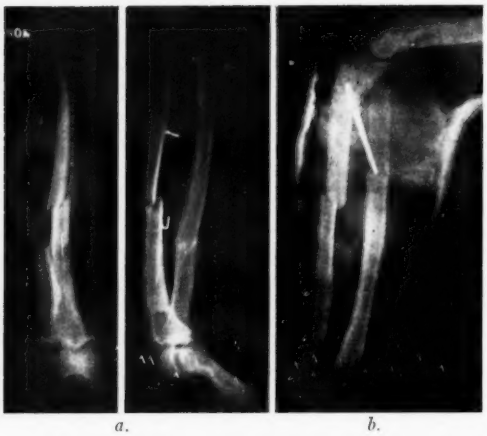
PRECAUTIONARY MEASURES

However, like many surgical procedures with merit, certain precautionary measures are noteworthy. The time limit of safety to work under the fluoroscopic X-ray is short, and during the surgeon's enthusiastic wrestle with unwieldy fragments, he must not forget this danger. Of course a satisfactory X-ray equipment is not always available, but this disadvantage does not apply alone to the pry-pin method. Most fractures of



a. *b.* *c.*

Fig. 2. *a*, Original deformity. *b*, Attempted reduction under anæsthesia. Deformity of ulna still exists. *c*, Reduction and retention with pry pin.



a. *b.*

Fig. 3. *a*, Retention after reduction failed three times. First attempt with pry pin was successful. *b*, Pin removed on fourteenth day.

importance now-a-days are transported to an X-ray, or an X-ray is brought in on the reduction problem.

Further, the pry-pin method requires working in the dark. This is only relative, since the greater X-ray vision is here far more important. Traction upon the leg or hand can be done as well without as with daylight.

It is true, aseptic surgical measures are difficult without ordinary light, but since the introduction of the pry-pin occurs but once and since its shaft can be well protected by sterile gauze, no practical danger is encountered by working in the fluoroscopic dark room.

Surgical anæsthesia is important for complete relaxation. This differs in no particular from the ordinary reduction, since complete relaxing anæsthesia is conceded essential in most fracture cases. It should be continued until the plaster

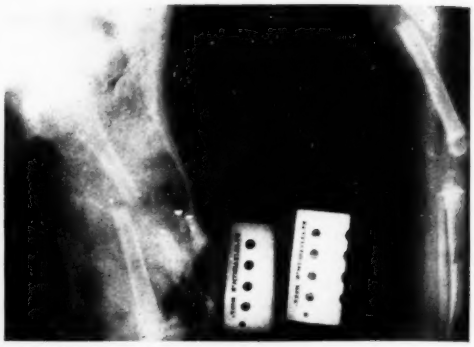


Fig. 4a. Fracture 2 weeks old. Three attempts at reduction failed. Child 4 years old. Dr. Thomson's case.

Fig. 4b. Pry-pin reduction speaks for itself. Pin removed on fourteenth day.

dressing is on and the pry-pin firmly incorporated in the same.

In a paper recently read before the Lancaster County Medical Society, my colleague Dr. J. E. M. Thomson recommended an extension of this lever principle in cases of large bones in very muscular individuals. Traction by hand aided with the pry-pin may not suffice to reduce the fracture in such individuals. A fracture table and

Fig. 5a. Fracture of femur 4 weeks old. Man 35 years old.

Fig. 5b. Double lever principle used in ope operation. Removed in 14 days.

TABLE I. CASE REPORTS

Case No. and Age	Bone	Usual reduction	Lever reduction	Lever removed	Convalescence	Result	Dr.
5988 12	Radius lower third	Impossible	Easy	10 days	3 to 4 wks.	Good	W
5170 40	Radius and ulna, lower third Ulna displaced	Impossible	Easy on 11th day	10 days	6 wks.	Good	W
6424 10	Radius and ulna, elbow	Lower third, radius failed	14th day	14 days	6 wks.	Slight bony atrophy	W
11374 15	Radius and ulna, middle third	Radius repeated failure	In 2 wks.	14 days	4½ wks.	Good	W
4562 45	Humerus, upper third	Failed	10th day	After cast was set	Uneventful	Splendid	T
6604 37	Tibia and fibula, lower third	Failed	4th day, tibia	After reduction	Uneventful	Slight limp Anatom. O.K.	T
6913 11	Radius and ulna, lower third (also humerus)	Failed	Both bones	8 days	Uneventful	Perfect	T
6782 10	Radius and ulna, lower third	Other doctor failed	5th day, both bones	Next day	Uneventful	Perfect	T
5623 30	Tibia and fibula, lower third	Oct. 30	Dec. 2, Tibia subcutaneous osteotomy	16 days	Uneventful	Anatom. O.K., Limp due to ankle injury	T
7003 18	Tibia and fibula	Manipulation unsatisfactory	Radius	After cast was set	Uneventful	Perfect	T
7136 32	Third metatarsal	Difficult	First day	Same date	Traction maintained	Anatom. perfect	T
7166 17	Radius, lower third	Failed	Same day	9 days		Perfect	T
6914 4	Femur, middle third	Other doctor failed 3 times	In 2 wks.	15 days	Uneventful	Perfect	T
4866 16	Clavicle, sternal third	Difficult	First day	After cast was set	Uneventful	O.K.	T
6588 54	Tibia and fibula, lower third	Failed	3rd day, fibula	5 days	Uneventful	Perfect	T
6905 35	Femur, middle third (old)	Failed	After 5 wks. double lever	14 days	Uneventful	Anatom. perfect, just out of calipers splint	T

W—Dr. Welch's case. T—Dr. Thomson's case.

mechanical traction is necessary. With such a table it is difficult to use the fluoroscope. Here it is that Dr. Thomson suggests introducing the index finger through a small incision to guide the lever between fragments and to judge the position of same as reduction is accomplished. In one such case he found a double lever very useful.

In recommending this pry-pin procedure after its successful application in a fair number of cases, I wish to summarize its points of value as follows:

1. The reduction of fragments occurs under the more favorable fluoroscopic observation, rather than the method of taking roentgenograms before and after reduction.

2. The principles are simple.

3. The danger to already damaged soft tissue about the fragments, by too vigorous manipulation during attempted reduction in difficult cases is greatly lessened.

4. The feature of retention of fragments is most helpful in selected cases.

5. Considering the method an open operation, it reduces the same to the minimum risk as such.

6. The use of the pry pin in compound fractures is not necessarily contra-indicated. The pin gives the added advantage of drainage.

7. No foreign body remains after 10 to 14 days, and no secondary operation is required.

8. No complications creditable to the pin *per se* have yet occurred.

9. Its limitations appear in the largest bones with strong contracting muscles, and where soft tissue intervenes between fragments, and where large vessels are too near, especially with pre-existing hæmorrhage of note.

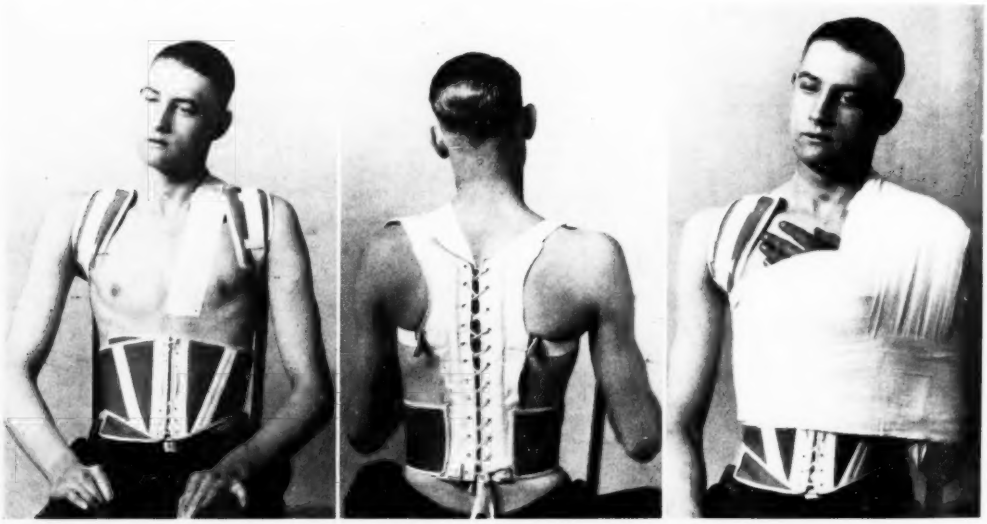
A COMFORTABLE APPARATUS IN THE TREATMENT OF FRACTURES OF THE CLAVICLE

By F. W. McGUIRE, M.D., F.A.C.S., Buffalo, New York

HIPPOCRATES treated fractures of the clavicle skillfully. The great objection to his method was that it was uncomfortable. If we look over our present methods we find the same objection still exists. If a dressing is uncomfortable it causes the patient to shift slightly and often, until it becomes more or less loose, thereby defeating its practicability.

The apparatus I am presenting holds the shoulder backward in a comfortable manner. The inner fragment is then brought into position by placing a flat bandage 2.5 inches wide over the inner fragment holding it in place by an adhesive plaster 2.5 inches wide and 15 to 18 inches long.

The arm on the affected side is placed at the side of the body and is held in position by a Velpeau dressing.



The principles involved in the treatment of fracture of the clavicle are the holding of the shoulder backward, upward, and outward. The most important of these is the backward position. As the shoulder is brought backward the outer fragment is brought into alignment.

The abdominal support compels the patient to stand erect and stabilizes the shoulder dressing. I have found this apparatus to be the most comfortable I have used.

THE INTRAVESICAL (CYSTOSCOPIC) TREATMENT OF CARCINOMA OF THE BLADDER BY IMPLANTATION OF RADIUM EMANATION TUBES

By A. HYMAN, M.D., F.A.C.S., New York

In reviewing the literature dealing with the treatment of bladder malignancy, it is apparent that a considerable change in the viewpoint of the urologist has slowly but surely taken place in the past decade. Until recently, practically all reports on this subject were concerned with surgical procedures, i.e., excision of the growth, or resection, with or without ureteral implantation. During the past few years, numerous articles have appeared describing the results obtained by a combination of surgery and radium, and in some instances, by radium alone. This change in attitude is due to the unfortunately poor results reported in those cases where surgery alone was used. As evidence of what may be expected from surgery alone, the following statistical studies are presented. In 1915, Gardner (5) collected 666 cases of bladder tumors operated upon by different surgeons, and found that in 224 cases requiring resection, recurrences took place in 43.7 per cent within 3 years after operation, while in 442 cases of excision of the tumor recurrences occurred in 88 per cent. Lower (6) reports 81 cases in which resection was performed; there was a mortality of 51.2 per cent, within the first year after operation. Scholl (7), from the Mayo Clinic, analyzed 168 cases of epithelial tumors operated upon. In the first series, of 71 cases described as malignant papilloma, 36.6 per cent of the patients died within a year following operation. Of 94 patients with solid carcinoma, over 71 per cent died within 7½ months after operation. The operative mortality following these procedures ranged between 10 and 15 per cent.

More satisfactory results have been obtained since a combination of radium with surgery has been employed, as indicated by reports of Barringer (1), Young (9), Buerger (2), Bugbee (3), Cunningham (4), Smith (8), and others, so that at the present time it may be stated that this combination offers the best therapy at our disposal in the treatment of bladder carcinomata.

The treatment of certain forms of bladder malignancy by means of radium alone, applied cystoscopically, although rather limited in its application, still has its field of usefulness. Its sphere up to the present time has been limited to a great extent on account of the difficulty in technique, the extra armamentarium required, and other factors that to a large extent have been overcome. The technique has been so simplified that the indications for this procedure will undoubtedly be broadened, and in certain selected cases will probably become the method of choice.

INDICATIONS FOR CYSTOSCOPIC RADIUM THERAPY

A few of the conditions in which the cystoscopic application of radium may be indicated, are as follows:

1. As an adjuvant to fulguration. In the treatment of papillomata of the bladder, the implantation of a few bare tubes into the base, or the application of surface radium has proved of considerable value. Young states that owing to the potential malignancy of all bladder papillomata, radium should be generally applied if possible. He is also of the opinion that the use of radium in benign papilloma of the bladder, followed by fulguration, gives results far superior to fulguration alone. Cunningham also advises the implantation of radium into benign tumors which are resistant to fulguration.

2. In aged and debilitated subjects, in patients refusing operation, or in cases where the surgeon deems operation inadvisable for various reasons.

3. In small pedunculated pathologically proved carcinomata presenting a benign appearance cystoscopically, with no evidences of infiltration or œdema around the base. This type of tumor designated malignant papilloma although successfully treated by fulguration alone is likely to recur following the application of radium.

4. In small recurrences following operative removal of the primary carcinoma and in the recurrences following fulguration of papillomata, it would be especially indicated. Inaccessible tumors, although they may be otherwise suitable for the intravesical application of radium, should not be treated, as it is absolutely necessary to have a clear view of the entire field of operation.

METHODS OF INTRAVESICAL RADIUM APPLICATION

The surface application of radium to bladder growths has been found to be unsatisfactory in most instances. This method required special cystoscopes and applicators, and necessitated the retention of the instrument in the bladder during treatment. Better results were obtained with the

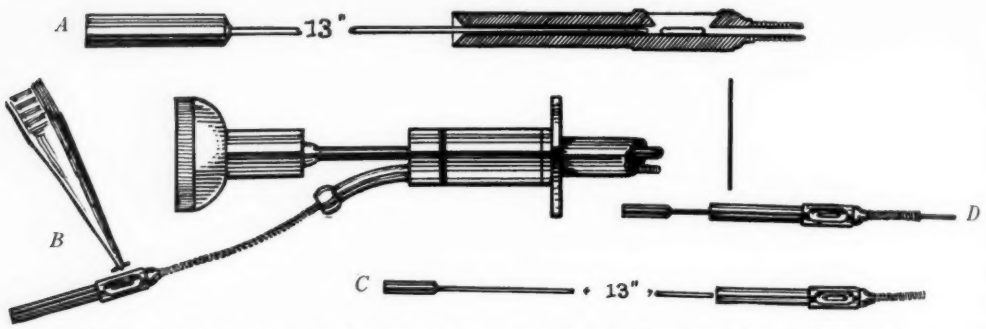


Fig. 1, *A*. Longitudinal section of loading chamber of Muir radium "seed" applicator, showing "seed" in place, ready to be pushed ahead by plunger.

B. Muir cystoscopic radium "seed" applicator, inserted into cystoscope, showing "seed" in forceps, ready to be placed in loading chamber of applicator.

C. Showing "seed" in place in loading chamber of "seed" applicator, inserted in cystoscope.

D. Wire plunger has pushed "seed" to a point near the needle opening. The operator now checks up the position of the needle before pushing plunger completely home. The "seed" is then placed into the predetermined position.

second method, which consisted in the introduction of radium-bearing needles directly into the growth. While the method is a great improvement over the surface radiation, it still offers many technical difficulties and disadvantages which have not as yet been overcome. A considerable advance was made in intravesical radium therapy when seeds or bare tubes of radium emanation were first introduced into the growth. It may be stated that at the present time the consensus of opinion seems to be that the best results in intravesical radium therapy have been obtained by the implantation of seeds into the growth. The technique of Barringer and Smith has been simplified by improvements in the seed applicator to be described, making the procedure one readily carried out by the trained cystoscopist. The instrument can be used through any ordinary operating or large catheterizing cystoscope, with direct or indirect vision.

Bare tubes or seeds of radium emanation are tiny capillary tubes containing the emanation of radium. The dosage of each tube can be accurately measured, the average seed containing between 0.5 and 1 millicurie of radium emanation. The radio activity of a 1-millicurie seed gradually decreases in strength, losing 16 per cent of its activity each day, so that at the end of about 6 days, the tube is practically inert. Such a tube gives off 132 millicurie hours of emanation and is sufficient to destroy 1 cubic centimeter of tissue. The necrosis caused by the seed is very complete and the slough produced takes from 2 to 3 months to separate. According to Smith (8), it is inadvisable to implant seeds in a growth having a diameter larger than 3 centimeters, as the resulting toxæmia from the necrosis of so large an area is likely to cause death. Larger tumors than this should always be attacked suprapubically and proper drainage instituted. The seeds remain in the growth until necrosis takes place when they are voided with the destroyed tumor tissue.

The seed applicator or introducer. The seed applicator or introducer, very simple in construction, is illustrated in the accompaning diagrams.[1] There are two types of introducers, one flexible, for use with the ordinary cystoscope, the other

[1] Devised by Dr. Joseph Muir.

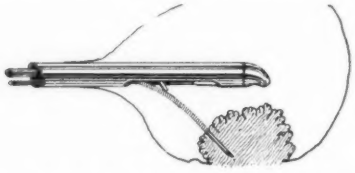


Fig. 2. Diagrammatic view of the tip of cystoscope with Muir cystoscopic "seed" applicator deflected, and inserted into tumor.

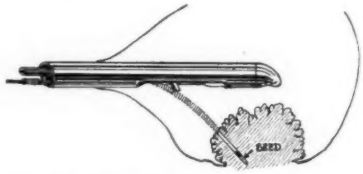


Fig. 3. Tip of cystoscope, showing position of "seed" when fully pushed home by plunger of cystoscopic "seed" applicator.

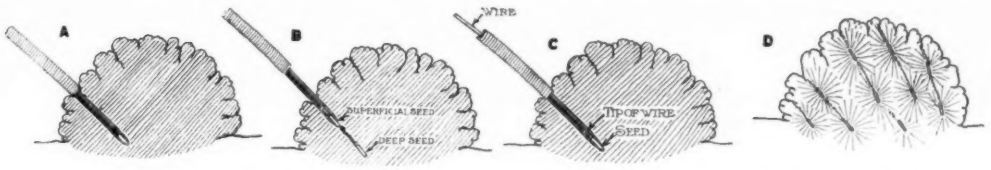


Fig. 4. *A*. Magnified diagram of "seed" applicator in tumor.

B. Same as View *A*, but showing a deep "seed" as deposited.

C. The same as in View *B*, showing a superficial "seed" deposited.

D. Diagrammatic view of cross-section of tumor, showing distribution of both deep and superficial "seeds."

rigid, adapted for the direct vision cystoscope. The design of both is otherwise identical.

The applicator consists of a long flexible hollow wire tube, with a small loading chamber at the proximal end in which the seed is placed. A wire mandrin is then introduced and serves to plunge the tubes into the growth.

The advantage of this new applicator lies in the fact that the seed is placed in the loading chamber at the proximal end of the instrument, instead of the opening at the distal end, as in the other types in use. This renders it easier and quicker to load, and prevents the seed from dropping out during the course of the manipulations. Another advantage of the applicator is that it can be loaded without withdrawing it from the cystoscope. It is therefore possible to introduce two seeds into one tract in the tumor, by simply withdrawing the introducer a short distance after the first seed has been implanted and then reloading the chamber with another bare tube. Much time saved is in the course of a treatment by this simple expedient of placing the seed chamber in the proximal end. We have on a few occasions planted over 20 seeds into a growth within three-quarters of an hour.

Technique of application of seeds. The procedure can be rendered painless by a preliminary novocain sacral anæsthesia, combined with an injection of novocain into the urethra and bladder. The cystoscope is introduced (the ordinary operating type of instrument is preferable), and the tumor brought into view. To facilitate matters, a nurse or assistant loads the chamber of the applicator which is then plunged into the growth, the mandrin is inserted, and the seed driven home. The method of implanatation varies with the size of the growth, and the dosage of the seeds. In general, it may be stated that seeds containing .5 to 1 millicurie should not be implanted closer than

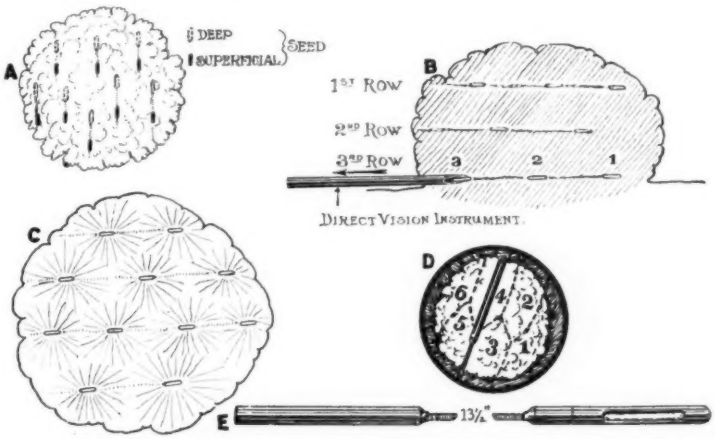


Fig. 5. *A*. Illustration showing the distribution in a typical tumor of both deep and superficial "seeds," as seen from above.

B and *C*. Plan and elevation of a typical tumor. The method of distributing "seeds" by means of a straight direct vision instrument (such as the McCarthy cystoscope), and the Muir cystoscopic "seed" applicator is clearly shown.

D. Diagram of cystoscopic view of high intensity applicator on tumor, showing by numerals the successive fields of application.

E. Muir high intensity radium emanation applicator.

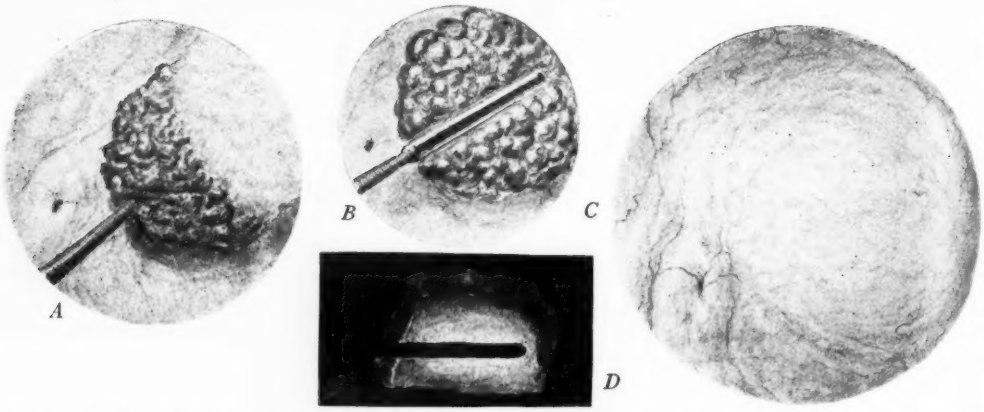


Fig. 6. *A*. Drawing showing a cystoscopic view of a sessile tumor of the bladder. The upper portion of the tumor is sloughing from former "seed" implantation. A flexible "seed" conveying needle is inserted into the lower part of the tumor.

B. Cystoscopic view of high intensity radium emanation tube applied to bladder tumor.

C. Complete regression of the mass in the same tumor.

D. Fluorescence obtained by the application of a high intensity radium emanation tube to fragment of willemite.

.5 centimeter. With smaller radiating units, more seeds may be employed. Our first work was done with seeds averaging .5 to 1 millicurie. We are now using seeds with a smaller dosage, .1 to .5 millicurie. The resulting necrosis is less marked and a more even and thorough radiation is obtained.

If the growth is a small one, the treatment may be completed in one sitting, larger tumors may require as many as three or four treatments. The seeds are implanted around the periphery of the tumor and then into the tumor itself, as schematically illustrated in the diagrams. Care must be taken not to implant them into the normal bladder wall, as the resulting necrosis may cause perforation. The nearer a tumor is situated to the vesical sphincter, the more care should be taken in the dosage employed, for the inflammmatory reaction following radiation of a tumor so situated is likely to be more severe than in a growth located further back in the vesical cavity. Following the implantation of seeds it may be advisable in the larger growths to apply surface radiation. This is readily accomplished with the surface applicator described. The reaction following the implantation of seeds lasts from 2 to 5 weeks and usually manifests itself by increased bladder irritability, burning, frequency, and dysuria. A second treatment should not be given until this reaction has subsided. At any event, there should be an interval of at least 2 to 3 weeks between treatments even though the reaction is slight, a longer interval, 3 to 5 weeks, is preferable. Within a few weeks following a radium implantation, the tumor presents a white, sloughing appearance. This slough may persist for 2 to 3 months before it is cast off.

CONCLUSIONS

1. In certain selected cases of bladder malignancy, the cystoscopic application of radium has a field of usefulness.

2. The results have been more satisfactory than with any other form of intravesical radium application.

3. The simplified technique required should render it the method of choice whenever endovesical radium therapy is indicated.

Following is a brief description of a case representing a type not infrequently encountered.

CASE 1. L. S., age 54 years, married, gave a negative family history. Twelve years ago he had an attack of left renal colic and passed a small stone. The present illness began eight months ago with increased frequency of urination, by day and night, accompanied by burning. There was no gross hæmaturia at any time, but terminal hæmaturia on a few occasions. At times urination was interrupted. There was no loss of weight, and the general health was good. Two months ago he consulted a urologist who made a diagnosis of carcinoma of the bladder and advised operation which the patient refused.

Physical examination. He was well preserved and adipose. Abdominal palpation was negative. The prostate was moderately enlarged and soft. The urine was cloudy, showing pus and red blood cells.

Cystoscopy. August 15, 1923. On the right side of the bladder, in the region of the right ureteral orifice, there is a solid looking spherical tumor, about the size of a medium sized plum. There is no œdema around the growth, which seems to be sessile. Lying on the trigone is a small, irregularly shaped calculus. There is moderate intravesical

prostatic enlargement. The rest of the bladder shows no abnormal changes. Specimens removed with punch forceps were papillary carcinoma. There were no evidences of infiltration of the base, cystoscopically or per rectum.

The patient refused operation, and radium therapy was then decided upon, August 22, 1923. Under sacral anæsthesia, 25 seeds averaging 8 millicurie, equalling 2,666 millicurie hours, were implanted into the lower half of the tumor which measured approximately 3½ to 4 centimeters in thickness. There was a moderate reaction lasting about 6 weeks, following this treatment.

October 10, 1923, seven weeks after radium treatment, a second cystoscopy showed that the entire lower half of the tumor treated was necrotic. Twenty seeds were implanted into the upper half of the tumor, the dosage equalling 2,128 millicurie hours. Surface radiation was applied, averaging 5 millicurie hours to a given area. There was a moderate reaction following this treatment, lasting about 3 weeks.

November 21, 1923, cystoscopy demonstrated that almost half of the tumor had already sloughed away and the remainder of the growth was entirely necrotic. At this examination the stone was removed by litholapaxy.

January 8, 1924, cystoscopy, 4⅓ months after the first treatment, showed that the entire slough had been cast off. The base of the growth was covered with a muco-purulent exudate which was surrounded by an area of œdema. There was no viable tumor tissue to be seen. The patient's subjective symptoms have almost entirely disappeared. The urine is still cloudy, containing a small amount of pus.

Addenda. October 25, 1924. Cystoscopy, a little over a year after the last radium treatment, showed a normal bladder. It was impossible to identify the former site of the growth. There were no subjective urinary symptoms.

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A SIMPLIFIED APPARATUS FOR TESTING THE PATENCY OF THE FALLOPIAN TUBES WITH ACCURACY

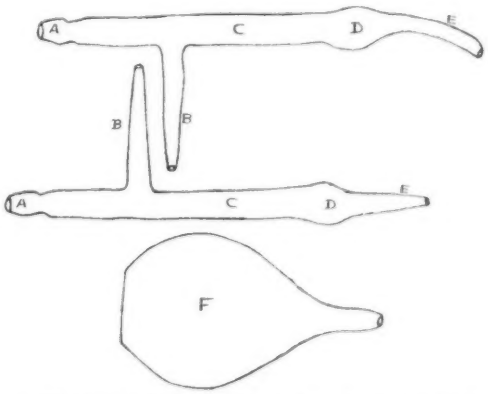
By ROBERT T. FERGUSON, M.D., F.A.C.S., Charlotte, North Carolina

After using for some time the apparatus designed by Dr. I. C. Rubin[1] of New York for testing the patency of the fallopian tubes, and after trying later the ordinary ear syringe with glass tube attached, without any attempt to register the amount of pressure in any given case, as practiced in so many hospitals and clinics today, I have devised the apparatus illustrated. The apparatus is equipped with a right angled glass tube attachment for a rubber tube leading to a mercurial manometer so that the pressure can be gauged at all times. This eliminates the danger of using too great a pressure and the possibility of rupturing the tubes with disastrous results.

The advantages claimed for this apparatus are simplicity; safety; negligible cost; the ability to sterilize as a whole; and the fact that a very small quantity of air can be injected into the peritoneal cavity as the pressure is under absolute control of the fingers and can be released instantly. Also patients complain of practically no discomfort following the test and are able to continue their vocation immediately.

The tube can be curved so as to meet any abnormal position of the uterus such as anteflexion or retroflexion or retroversion, or if preferred it can be attached to the ordinary Keyes-Ultzman syringe by a short rubber tube connection.

[1] J. Am. M. Ass., 1920, Sept. 4.



a, Tip for attachment of rubber bulb; *b*, tip for attachment of rubber tube leading to manometer; *c*, glass tube; *d*, bulb which plugs cervix and prevents escape of air; *e*, tip for insertion into cervical canal; *f*, rubber bulb (ordinary ear syringe.

I claim no originality except for the offset on the glass tube by which it is possible to attach a rubber tube to manometer and the bulb near the tip to prevent escape of air from uterus. This may have been used before but I have never seen it used or described. I have found it an almost indispensable piece of apparatus.

EDITORIALS

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DECEMBER, 1924

STRICTURE OF THE COMMON BILE DUCT

STRICTURE of the common bile duct, while fortunately infrequent, has serious results because of interference with the normal flow of bile.

The structure of the common duct is similar to that of many other tubes of conveyance. It is lined with a columnar epithelium, outside of which is an elastic layer and a very thin muscle layer composed of only a few scattered bundles; on top of this layer is a coat of fibrous tissue. It is doubtful whether there is sufficient muscle tissue in the duct to produce contraction, and it is not known whether or not the bile is urged on by peristaltic contractions. The duct can be greatly dilated and yet apparently maintain its function. Often one or more stones are found wedged, under considerable pressure, into it, apparently completely destroying the mucous lining in that area, and yet strictures seldom occur under such conditions. In a review of a large number of cases in the Mayo Clinic, in which operation had been performed for disease of the common duct, in only four did it appear that a stricture had developed in the duct as the result of trauma from the pressure of impacted stones. Furthermore, these strictures were not complete; they allowed a certain amount of bile to pass, and therefore were less serious than is sometimes the case. In view of the fact that pressure from an impacted stone must often produce necrosis of some of the tissue layers composing the duct, it is fortunate that the mucous membrane does regenerate rapidly.

Stricture of the common duct, following removal of the gall bladder, must be the result of technical error, and yet there are cases in which it is difficult to explain its occurrence. It is impossible to overemphasize the importance of isolating the lower end of the gall bladder and cystic duct before applying clamps, in the performance of a cholecystectomy. If this is done, a stricture will never occur. The idea that the entire cystic duct should be removed in performing a cholecystectomy is apparently wrong, for so far as the results are concerned, it is unnecessary; and moreover attempts to remove the duct completely may cause enough disturbance in the surrounding tissues to result in stricture of the common duct. The number of instances in which the stump of a cystic duct has caused trouble does not warrant consideration. Common duct stricture may be divided into three groups, according to the manner in which the symptoms present themselves.

Group 1 includes those cases in which jaundice develops shortly after cholecystectomy, but in which there is never any drainage of bile, and the early convalescence seems normal. The jaundice increases rapidly from the onset, and within a few weeks the patient

presents a typical picture of complete jaundice. Usually there is no pain, although there may be attacks of rather sharp colic following which the jaundice deepens considerably. On re-operating in these cases, the common duct has usually been found to be completely severed or entirely closed by firm stricture. At times the only evidence of the duct is a little bud on the under surface of the liver at the site of the common duct. It is difficult to determine just what occurred at the time of the first operation, but probably the operator was unaware of trauma to the duct, and yet in some instances, the absence of an inch or more of the extrahepatic ducts has been discovered. In some cases the duct may have been severed and tied, or else entirely included within the tie on the cystic duct or vessels.

Group 2 differs from Group 1 in that, a few hours after the gall bladder has been removed, bile drains freely from the wound, and this continues throughout the convalescence. In many instances it can be demonstrated that all of the bile is draining through the post-operative wound and none is passing into the intestinal tract. Such drainage usually continues for a few weeks, then decreases gradually, and jaundice develops. The wound may open a few times and drain bile before it closes permanently. In these cases, also, the common duct will be found to be completely closed by stricture, and often the distal part of the duct cannot be located.

Group 3 consists of interesting cases in which it is difficult to explain the cause of the trouble. The characteristic feature is that the patient has a normal or nearly normal convalescence following cholecystectomy and for six months or more is entirely well, in most instances being able to return to his work. Then, without any warning, jaundice appears. It may be intermittent at first, but later constant, and usually never entirely disappears. Sometimes these patients have attacks of severe pain, chills, and fever, and a diagnosis of common duct stone is often made. It should be stated that in many cases of common duct stricture, small stones are found above the stricture area, but undoubtedly they are secondary to the obstruction of the common duct. In this group the jaundice gradually deepens, and in a few weeks becomes complete. If the old operative field is exposed, the common duct will be found to be completely closed; in most of these cases, a part of the duct is missing, and it lacks continuity. In view of the fact that the duct must have been patent for at least six months after the removal of the gall bladder, it is difficult to explain what happened at the time of the cholecystectomy that would account for this condition six months later. Eleven patients in this condition have been observed at the Clinic, all in a state of complete jaundice at the time they presented themselves. It would seem that adhesions gradually contracting, making pressure, and finally resulting in necrosis, might explain some of the cases. Likewise, it has appeared that as the result of using a large amount of gauze drainage, especially around the duct, a marked reaction in the tissues might finally have caused the stricture. And it is possible that in an attempt to remove the entire cystic duct, the circulation in the common duct was interfered with, so that the tissue in the duct was gradually replaced by scar tissue.

Although one is at a loss to know how to explain just how and why these strictures develop, nevertheless it may be said that if at the time of the operation for the removal of the gall bladder, the lower end of the gall bladder and the adjoining portion of the cystic duct are completely isolated before clamps or ligatures are applied, strictures will not occur.

E. Starr Judd.

POISONING BY PROTEIN SPLIT PRODUCTS: ITS IMPORTANCE IN SURGICAL PRACTICE

THAT intoxication with protein cleavage products may lead to certain pathological manifestations has long been recognized. Until recently, however, the clinical importance of this had been clearly established only in regard to those conditions which were of interest to the physician rather than to the surgeon. Of late, more and more evidence has been accumulated to indicate that disorders which properly come within the domain of surgery owe their origin to this form of intoxication.

Acute anaphylactic shock represents an unquestioned example of poisoning by protein split products. In this condition, as is well known, there occur histological changes in certain organs, especially the kidneys and the intestines. Along with these structural changes, the composition of the blood is altered; an increase in the non-protein nitrogen and a fall in the chlorides taking place. It appears that there is an initial increase and a late decrease in the hydrogen-ion concentration of the blood; or, expressed differently, the alkali reserve first falls and then rises.

In intestinal obstruction, symptoms occur which resemble those seen in anaphylaxis. It has long been felt that the poison responsible for these manifestations is a protein derivative, and this appears to have been confirmed by the demonstration of histamine in the lumen of the obstructed bowel. Furthermore, changes in the kidney and in the intestine similar to those occurring in anaphylactic shock have been observed after death from intestinal obstruction; and in both conditions there is seen the rise of blood nitrogen and the fall in the chlorides.

It seems extremely probable that secondary traumatic shock is often the result of poisoning by protein cleavage products. The blood concentration, the rise in the non-protein nitrogen which occur in traumatic shock resemble the changes seen in anaphylaxis; and the striking similarity in the circulatory reactions in shock and after the injection of histamine support the view that protein split products, arising in the traumatized muscles, are responsible for the changes which take place in the former condition.

In peritonitis, likewise, there is little question but that we have an instance of protein cleavage product intoxication. When the peritonitis arises from intestinal perforation, conditions ideal for the decomposition of the protein seem to exist, since there is present an albuminous fluid, teeming with proteolytic bacteria. That toxic substances derived from protein are actually produced and give rise to the symptoms is rendered likely by the histological changes which are produced in such organs as the intestine and the kidneys; these changes resembling those seen in anaphylactic shock and after death from intestinal obstruction. In peritonitis, also, changes occur in the blood identical with those that have been described in traumatic shock and, in certain respects, similar to those seen in intestinal obstruction and in acute anaphylactic shock.

Of especial interest, however, are the recent observations on the pathological disturbances following extensive superficial burns. That an organic poison was produced in the burned tissue and was responsible for the toxæmia and death which often occurred after such burns is not a new idea; and it was known, further, that characteristic histological changes occurred in persons or animals dead of such burns; these histological alterations occurring in the suprarenals, the kidneys, and the intestines and being, apparently, identical with those described as existing in other instances of protein derivative intoxication. The recent

experiments mentioned have furnished proof of the existence of the poison in the burned tissues and of its transport by the red blood corpuscles.

What is the obvious lesson of these observations? Experimentation is of little value, unless it leads, directly or ultimately, to improvement in our therapeutic methods. Laboratory workers have shown that the removal of crushed muscular tissue will prevent the development of shock symptoms in experimental animals; army surgeons have successfully applied this method of treatment clinically; the explanation for the good results in both instances being that the source of the poisonous cleavage products is removed by the process of "débridement." Similarly, it has been shown, both by experiments on lower animals and by clinical trial, that a like good effect follows the application of this principle in the treatment of diffuse peritonitis. By saline irrigation and suction, the decomposing peritoneal exudate may be removed effectively, and the striking immediate improvement in the patient can be likened to nothing more appropriately than to the result of the use of antitoxin in the treatment of diphtheritic infection.

It has been found that by removing burned tissue from one animal and engrafting it into another the toxæmia will be prevented in the first and developed in the second animal. Such a result as this would seem to offer a logical argument for the employment of "débridement" in the treatment of burns. To suggest the removal of all the tissue killed by the burn may appear to be ultra-radical; but when it is borne in mind that this tissue will eventually be sloughed off, during the course of which poisons will be produced locally that will seriously injure the patient, justification is seen for such a procedure. By boldly removing this dead tissue, the patient is spared the intoxication which would otherwise occur; and, moreover, the process of local healing is much hastened. If sloughing is allowed to take place, healing is accomplished by slow granulation; if the dead tissue is removed cleanly, healing by first intention will be the result. Of scarcely less importance is the relief from pain; the comparative comfort of the patient being a great contrast to the suffering which is an invariable accompaniment of the older conservative methods of treatment of burns.

The surgeon who applies the method of débridement in the treatment of severe superficial burns cannot fail to be impressed by the lessening or prevention of toxæmia; the hastening of local healing; and the relief from suffering afforded the patient.

A. Murat Willis.

MASTER SURGEONS OF AMERICA

JAMES EDWARD MOORE

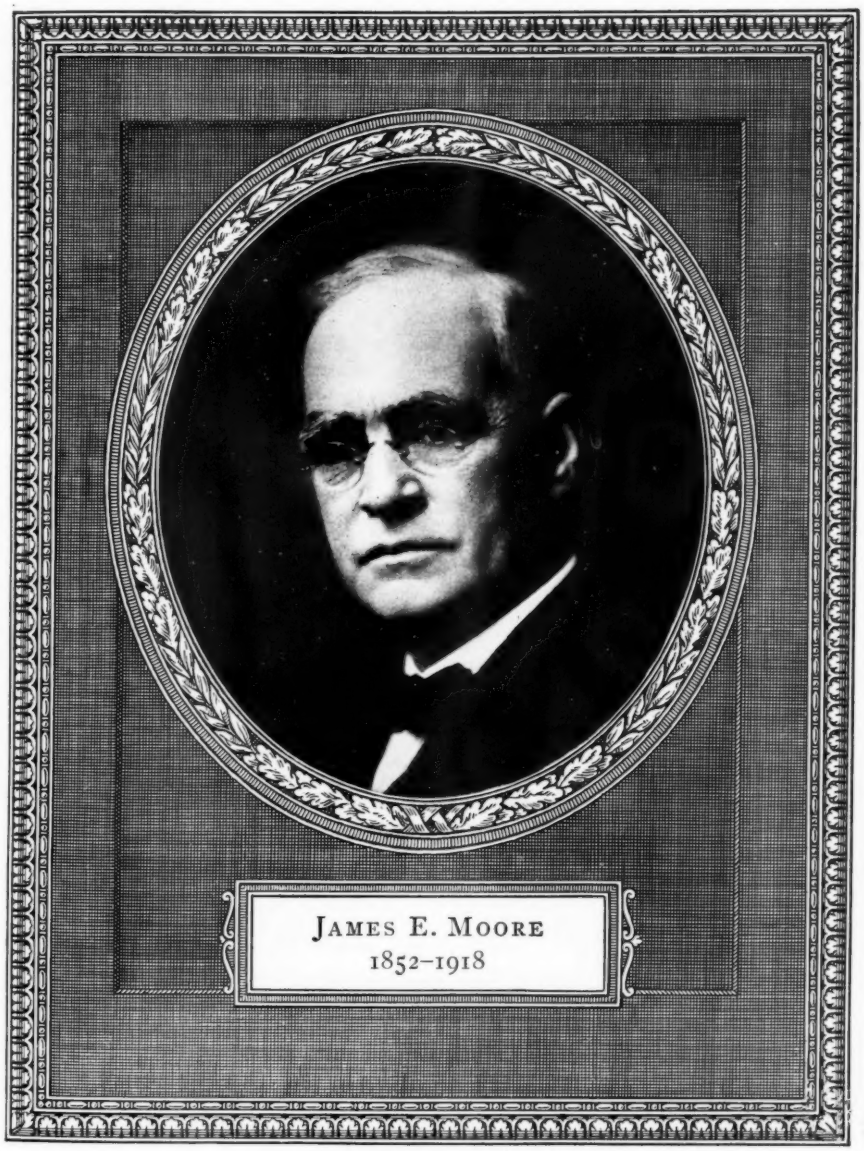
JAMES EDWARD MOORE was born in Clarksville, Pennsylvania, on March 2, 1852 and died in Minneapolis, Minnesota, November 2, 1918, of pernicious anæmia. He was the son of the Reverend George W. and Margaret (Ziegler), Moore.

He received his preliminary education in the public schools of Pennsylvania, later attended the Poland Union Seminary at Poland, Ohio, subsequently the University of Michigan, receiving his medical degree from the Bellevue Hospital Medical College of New York in 1873. The year following his graduation he practiced in Fort Wayne, Indiana. He then returned to New York for post-graduate work in the hospitals. In 1876 he established himself in Emlenton, Pennsylvania, where for six years he performed the arduous work of a country practitioner, making most of his calls on horseback and dispensing from his saddle-bags.

In 1882 he moved to Minneapolis, Minnesota, and practiced there as a general practitioner until 1885, when he went to Europe and studied in London, Paris, and Berlin. Returning to Minneapolis in 1887, he announced himself as specializing exclusively in surgery. He was the first specialist in surgery west of New York to so announce himself.

Always profoundly interested in medical education, upon the organization of the medical school of the University of Minnesota, Dr. Moore was appointed one of the faculty of that institution. He held in succession the positions of professor of orthopedic surgery, professor of clinical surgery, and professor of surgery. In 1904 he was made chief of the department of surgery and held this position until his death on November 2, 1918.

Dr. Moore was blessed with the rare gift of imparting knowledge; he was a born teacher. He presented his subjects in a simple, terse, logical manner. With a splendid command of English, with an earnest enthusiasm, with a native dignity and a quiet eloquence, his logical summaries carried conviction. He was forceful and emphatic, yet temperate and restrained in all of his utterances and his actions. He contributed generously of his money, of his time, and of his energy to the upbuilding of the medical school. The welfare of this school was very close to his heart. Successive generations of students sat at the feet of this master



JAMES E. MOORE
1852–1918

teacher of surgery, of whom it has been said that he was one of the four great teachers of surgery in the United States. He was a virile, lucid, convincing writer. He was the author of a number of chapters contributed to the various American systems of surgery. In 1885 he published his work on *Orthopedic Surgery*. The literature of surgery has been greatly enriched by his contributions to that science, he having written and published over 200 papers on surgical subjects. His writings and discussions won him recognition at home and abroad, and he early became identified with the representative surgical societies, being a fellow of the American Surgical Association and its vice president in 1905; a fellow of the Western Surgical Association and its president in 1902; a fellow of the Southern Surgical Association; chairman of the surgical section of the American Medical Association in 1903; a member of the judicial council of the American Medical Association; a fellow of the American College of Surgeons and a member of the Board of Governors; a member of the Société Internationale de Chirurgie; a member of the Minnesota Academy of Medicine, and of all the local state and county societies.

Perhaps more than any one man who has passed into the great beyond, James Edward Moore left his imprint upon the profession of the middle west. His renown as a teacher of surgical subjects spread beyond the confine of his own territory and the influence of that teaching was disseminated over the land through the hundreds of students who are privileged to reflect his influence. His devotion to the University Medical School was proverbial, a devotion which unquestionably shortened his life.

In February, 1910, while lecturing to the junior class of students in an old building which had been partially destroyed by fire, the ruins of a brick chimney fell and buried him in the débris, injuring him so severely that for days his life was despaired of. His former robust health was never regained. His health failing, he retired from the practice of surgery in 1915 and for the rest of his life devoted himself entirely to surgical teaching and surgical clinics at the University of Minnesota.

Dr. Moore was as much a victim of the Great War as though he himself had gone "over the top" and paid the supreme sacrifice in Flanders or on the fields of France. His high sense of duty unquestionably shortened his life. In 1917 and 1918 the Great War drained the medical school of the University of Minnesota as it did all other medical schools, of its teachers. This threw an added burden upon those who were left, a burden which was doubly difficult to bear when laid upon the shoulders of a man already frail and well along in years. Uncomplainingly he shouldered the added burden feeling that he was doing his "bit" in helping to do the work of his absent "boys" who were over-seas. The strain, anxiety, and overwork but hastened a breakdown made inevitable by his insidious disease.

To the many who were permitted to know Dr. Moore well and to the few who were privileged to be his intimates, the charm of his personality, his simple manly creed, his love of justice and fair play, his intolerance of incompetence and sham, his charity for human weakness and frailty, his keen appraisement of character, his fearless championship of right and, above all, his great human sympathy for those in trouble or distress,—one and all were traits which appealed and bred love, respect, and deference.

For 36 years this Nestor of the profession of the northwest left a serious imprint on the medical life of his community. The influence of his example, skill, and teaching on the medical life of the middle west through these formative years helped to blaze the trail and to mold, stimulate, and standardize the surgical trend of medicine toward the very highest type.

As a teacher, surgeon, and friend he was a constant inspiration, his life a model which helped to shape the destinies of his students and inspire the emulation of his fellows. He illustrates the old poem—

> "The heights by great men reached and kept
> Were not attained by sudden flight.
> But they while their companions slept
> Were toiling upward in the night."

ARTHUR A. LAW.

TRANSACTIONS OF SOCIETIES

CHICAGO GYNECOLOGICAL SOCIETY

REGULAR MEETING HELD JUNE 20, 1924, DR. CHARLES S. BACON, PRESIDING

CYSTADENOMA OF THE OVARY; CONGENITAL DIAPHRAGMATIC HERNIA

DR. GALLOWAY reported a case of cystadenoma of the ovary in a woman 24 years of age, who was married and had had no labors. The main thing about her history was metrorrhagia and menorrhagia with periods of bleeding as long as 20 to 25 days. She had also noticed an enlargement or tumor mass in the lower abdomen. The tumor mass extended 2 to 3 centimeters above the umbilicus. She was operated on about 10 days later and the right ovary was a symmetrical mass about 7 inches in diameter, quite hard and not adherent. It had a pedicle that was twisted one and one-half times. The uterus was small and normal and the left ovary and tube were normal. The mass was removed without any shock to the patient and she made a complete recovery.

There were areas of cystic degeneration throughout the tumor mass and it was mostly composed of hard fibrous connective tissue. There were areas of necrotic epithelium lining some of these spaces.

DR. GALLOWAY reported another case, that of a primipara, age 24, who went into labor about 2 o'clock in the morning and was delivered about 11 o'clock the same night by simple low forceps.

The baby did not breathe, at least we could not get it to breathe, though the heart beat. The queer thing about the case was that the heart beat was on the right side and could be felt in the anterior axillary line. The baby was of fair color when it was born. The tracheal catheter did not do any good. There was difficulty in getting any respiration even with the tracheal catheter in.

We did not have a complete autopsy on the case. The condition turned out to be a congenital diaphragmatic hernia on the left side with almost all of the abdominal viscera in the left side of the chest. The left lung was compressed down to nothing but a piece of tissue the size of a fifty-cent piece. The heart was pushed to the right side.

On looking up the literature I found that one man had reported 635 of these cases, of which 520 were left sided. Keith analyzed 35 of these herniæ very well and said that the liver protects the right side to some extent and that the embryological development of the diaphragm permits the descent of the diaphragm which takes the phrenic nerve with it, so that apertures are formed through which the lungs are allowed to go to their position in the thorax. These apertures close later on. Those on the right side close before those on the left and the position of the liver helps them to close. If that aperture remains open the possibility of hernia is quite likely.

DISCUSSION

DR. IRVING F. STEIN: In 1914 I published a case in SURGERY, GYNECOLOGY AND OBSTETRICS almost identical to the picture Dr. Galloway has shown in which we found the heart on the right side. The baby lived 26 days. During that time we made X-ray studies which showed the stomach well into the chest, and the diaphragm which reached the second rib was thinned out to a fibrous partition. All of the abdominal organs were in the chest. The baby failed to thrive and died in cyanosis

DR. W. C. DANFORTH contributed a paper entitled, "A Criticism of Certain Tendencies in Obstetrics."

FIVE YEAR END-RESULTS OBTAINED IN CARCINOMA OF THE PELVIC ORGANS WITH RADIUM AND X-RAYS

DR. HENRY SCHMITZ read a paper on "Five Year End-Results Obtained in Carcinoma of the Pelvic Organs with Radium and X-ray." (See page 775.)

DISCUSSION

DR. EMIL RIES: Every time I listen to a discussion on the treatment of carcinoma of the cervix by radium I am more bewildered than before. Here we have reports of cases which to all intents and purposes were hopeless, staying cured for five years. There is a wide discrepancy between these statistics and the rationale of the method. We are told right and left that the X-ray does not cure carcinoma. The theory now is that the X-ray produces certain substances which kill the carcinoma. Then why did death result in the cases in Class I or Class II when in Class IV the substances produced by the X-ray or radium gave a cure?

The technique of radiation treatment of cancer is not clearly presented by physicists whose idea of carcinoma is that it is like a button; they want to reach that button and if you reach it with enough ray that is all that is necessary. They do not know anything about lymphatics or about the spread of

carcinoma. It is not the action of the rays on that button but the action on the system which produces curing factors. As it stands now the theory is absolutely bewildering. Nevertheless there is the outstanding fact that cases that we cannot handle with any kind of operation have done well under the treatment described.

As far as operation is concerned, it should be really radical. The Wertheim operation is entirely wrong because tissues are left standing between the primary cancer and the lymph glands. Also a radical operation in which no attempt is made to remove the lymph glands as extensively as possible is not a radical operation. The Wertheim operation has become popular because it is much less dangerous as to primary mortality than my operation. No one knows what a really radical operation will do because it has not been carried out in enough cases. I am not speaking of my own cases because I have not had 100 cases and the chances of bringing you 100 cases in the near future are becoming less because since the advent of radium and the X-ray practically all patients to whom you tell the truth about the operative mortality very naturally take their chances with radium or the X-ray rather than the risk of dying within a few days from the operation. I hope radium and the X-ray will be so perfected that we can abandon operating altogether, but I am not ready to do it. Whenever a patient comes to me I tell her truly the results of the radical operation, the primary mortality, the number of recoveries and the results from the use of radium and the X-ray. I have, therefore, very few cases who come to operation. I have not operated upon a single case of carcinoma of the cervix this year. I have 5 patients who for 5 months have been under radiation therapy. They were all inoperable when they came to me but I can report cases that I operated on many years ago. Last Christmas I had a card from a woman I operated upon in 1901, 23 years ago. She had an enormous carcinoma of the cervix, and the lymph glands along the iliac were so big that the biggest one was the size of the end of my thumb and she is alive today. I have one patient living upon whom I operated in 1897. She lives in Texas and I have a report from her physician that she is alive. This one had no carcinoma in the lymph glands. Wertheim once made the statement that no patient in whom he found a carcinoma of the lymph glands ever lived. All the patients with inoperable carcinomata whom I have turned over to the X-ray men are dead.

As far as my recurrent cases are concerned I have not one patient who has lived over a year. I do not treat them. I turn them over to the radium and X-ray men.

Dr. A. H. Curtis: Our results from operation on carcinoma of the cervix have been extremely disappointing. Dr. Watkins has not entirely given up operating on the cervix cancer but I have done so for the present at least. I do not know what my attitude will be five years from now. I would estimate that we are able to obtain permanent cures in twice as many patients through radium and X-ray therapy. Dr. Jones works both with Dr. Watkins and with me so he has an opportunity to compare results; he is strongly of the opinion that even in "operable" cases radium and X-ray are preferable to operation.

Dr. Mark T. Goldstine: I believe that there are certain carcinomata of the cervix, early ones, that will get well no matter what treatment you use. Byrne of Brooklyn cured some early carcinomata of the cervix by cauterization. There are polyps in the cervix that are early carcinoma and if the polyp is removed a cure may result. I have had a number of cases in which a polyp was removed early from the cervix and diagnosed carcinoma. Later on when the uterus was removed and sections made of it, we could not find any evidence of carcinoma in hundreds of sections. If all the carcinoma tissue can be removed with the knife or radium or if an ordinary hysterectomy is done, there is a chance of cure.

That brings up the point of how many carcinomata of the cervix are cured with radium or X-ray or any treatment. When I have used the radical method I have had a high mortality. I have patients living 9 to 12 years upon whom I used the operation I have described. Two years ago a woman came with a mass in the cervix just inside the external os. We removed a part of the mass and diagnosed it adenocarcinoma. She left without treatment. I saw her two weeks ago. She said "I am perfectly well; I have not lost any weight; I am all right." She had nothing but a curettage by another surgeon.

As long as I can find one lymph gland I will not trust to radium or X-ray. Carcinoma does not occur in the lymph glands often. Just as long as I find once in a while a gland that is carcinomatous I am going to stick to surgery and advise what I think is a radical operation. Our operation is still not radical enough, because we find some very difficult cases in which the carcinoma of the cervix is near the anterior wall of the rectum and hard to dissect out.

Dr. Henry Schmitz (closing): I probably may have anticipated some of this discussion and, therefore, stated the results for the clinics of Dr. Clark and Dr. Kehier who have treated a large number of cases by X-ray and have had the same results as I have. X-ray and radium do not act in the same way. The treatment is specific. We do not know that it cures. Before we knew anything about the causation of carcinoma we were able to cure the cervix fairly well. As soon as we learn a specific cause of carcinoma then we will be able to correctly interpret all these clinical observations which we make now. We have attempted to go into the study of the action of radium and there are two investigations which we have made which are really of great interest. It has been proved that a patient with cancer develops a serum and it is the lytic power of this

serum which digests the cancer cells. In 1912 some cases were reported in which the cancer was removed surgically, one of the rectum and one of the breast. They were also shown not to possess any lytic power but after operation they acquired this. About a year or two ago we took about 25 consecutive cases and after working with serum made from the patients we obtained some carcinoma serum from Vienna. In 15 of the cases after radium and X-ray application there was a reestablishment of carcinoma power within eight days after the treatment. We could not explain why this happened. We went ahead and had about 35 cases of cancer of different types, cervix chiefly, and we made a determination of the non-protein nitrogen, urea, and creatinin constituents of the blood. We found that in the cases that we had treated with the X-ray there was a marked increase in the nitrogen tolerance. If this increase persisted that patient would very probably succumb to the disease. On the other hand, if the blood went back to normal in two or three weeks the patient was clinically improved. There were some patients who did not get any reaction at all and still in these the conditions were most advanced. Therefore, we concluded that in patients with advanced carcinoma suffering from auto-intoxication it is not worth while to use radium or the X-ray because they have not the power to activate the necessary toxins to overcome the cancer cells. We must remember that any method that enables us to remove or destroy any particular cancer cell will cure the patient. It does not make any difference what we use. As long as it is possible for us to eradicate all the cancer cells I am perfectly willing to admit that we cure the disease.

CORRESPONDENCE

REMOVAL OF NEEDLE FROM TISSUE WITH THE AID OF THE FLUOROSCOPE

To the Editor: I have found the removal of needles a difficult matter because it is impossible to locate them even though X-ray films have been made. I have found that the following method converts the situation into an easy one.

Over the site of the needle, which is usually evident (if not the X-ray will give the general location), an incision is made, under local anæsthesia, through the tissues to a reasonable depth. The site of the incision is marked by picking up a little of its tissue with a mosquito tissue forceps. With the wound under the fluoroscope, a second hæmostat is inserted into the wound and under visualization of the fluoroscope, is guided to the needle which is grasped, the hæmostat made fast, and the needle removed. This is easily accomplished in a light room.

F. R. Makinson, M.D.

Oakland, California.

THE USE OF LEVERAGE IN THE REDUCTION OF FRACTURES

To the Editor: Since the appearance of my article on "The use of Leverage in the Reduction of Fractures," which appeared in the September number of Surgery, Gynecology and Obstetrics, I have had a number of inquiries in regard to the type of dental probe that I use in carrying out this technique.

The "dental probe" is the dental hatchet, the spoons, the file or almost any long handled straight dental instrument. It is our custom to file off the end of the instrument before using it for leverage purposes.

J. E. M. Thomson, M.D.

Lincoln, Nebraska.

REQUEST FOR BACK NUMBERS

To the Editor: I would like to call attention through your columns to the fact that there are many foreign physicians and surgeons who cannot afford to purchase Surgery, Gynecology and Obstetrics who would appreciate very much receiving the journal.

If any subscribers who do not keep copies for binding would send them for this purpose to my address, I shall be pleased to receive and forward them.

Rosalie S. Morton, M.D.

100 Central Park South, New York City.

THE SURGEON'S LIBRARY

OLD MASTERPIECES IN SURGERY

By ALFRED J. BROWN, M.D., F.A.C.S., Omaha

THE PENTATEUCH AND OPERATIONS OF SURGERY BY HIERONYMUS FABRICIUS OF ACQUAPENDENTE

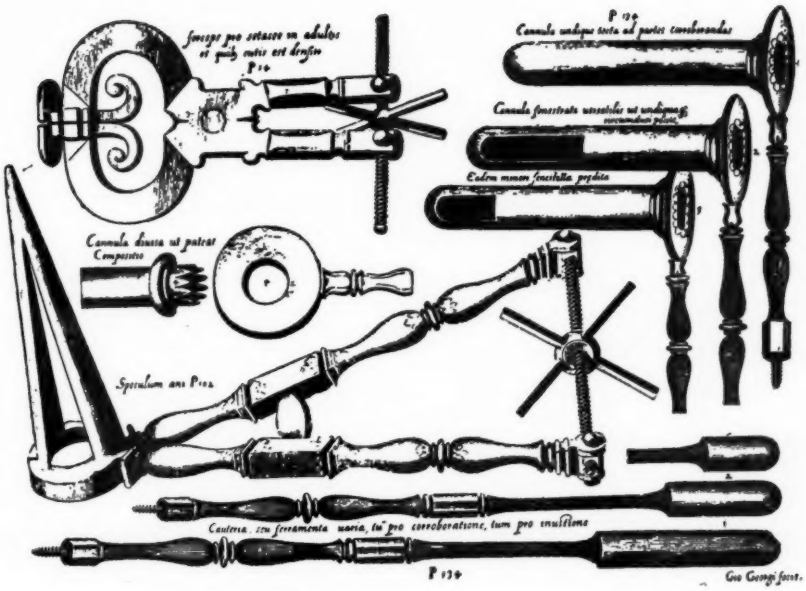
DURING the latter half of the sixteenth and beginning of the seventeenth centuries, progress and advancement in medical science centered in Italy and particularly at the great school at Padua, which produced many of the great medical men of the period. Among these was Hieronymus Fabricius. Born of a middle class family in Acquapendente in Etruria in 1537, he decided to take up his medical education at the University of Padua. By his application and intelligence he attracted the attention of the then Professor of Anatomy, Gabriel Fallopius, and became his special student and assistant both in the anatomical department and in his practice. During this time he began his study of the valves of the veins which, though not wholly unknown, were but little understood. His enthusiasm for this subject he later transmitted to one of his students, William Harvey, who carried it out to its conclusion and published the discovery of the circulation of the blood in 1628, nine years after Fabricius' death.

After the death of Fallopius, Fabricius, though only twenty-five years of age, was entrusted with the anatomical demonstrations and three years later, in 1565, was appointed professor of surgery in the University of Padua by the Republic of Venice. Six years later he was appointed professor of anatomy and held this position until 1604 when he relinquished his work at the University and passed it on to his assistant Guilio Casserio. In addition to his work at the University, Fabricius enjoyed a very large practice, possibly because of his sanity and conservatism, and received many honors from his state and his city. He was made a Knight of St. Mark by the Republic of Venice and presented with a golden necklace and was made an honorary citizen of the city of Padua. His practice must have been a very lucrative one for he built an anatomical theater for the University at his own expense, maintained near the city a large estate named "La Montagnola," and at his death in 1619 left a fortune of two hundred thousand ducats.

Fabricius' first surgical work was published in 1592 by Joh. Hartmann Beyer at Frankfort. This was called "The Pentateuch (Five Books) of Surgery." These books are entitled I. Tumors, II. Wounds, III. Ulcers and Fistulæ, IV. Fractures, and V. Dislocations. In 1617, two years before his death, the work was published in an enlarged form and the second part, "The Operations of Surgery," added. These two works were reprinted many times and the volume must have been considered authoritative for its republication is noted every few years up to 1729.

The general plan of the work differs but little from the other surgeries of the time. The division of the surgery into books or headings is the same as many others but owing to the author's scientific trend of mind and the application of his anatomical knowledge to the clinical field, he discards much of the necromancic and spiritualistic and bases his ideas on then known scientific fact. He knew the work of the older authors who were considered authorities, Celsus and Guy de Chauliac in particular, but does not hesitate to criticize their opinions when they do not agree with his own observations. The book on tumors contains, as all the surgeries of the time, inflammations and their sequellæ, swellings of all kinds including œdema, and hernia. Among other things it is worthy of note, that he was the first to differentiate goiter from other tumors of the neck. In the book on wounds Fabricius describes the ligature of vessels in connection with vascular wounds but does not mention Paré and as he usually gives credit to previous writers it is probable that Paré's method and teaching had not as yet reached Italy. In connection with fractures he describes and illustrates several complex machines for setting and holding fractures. The illustration of his *οπλομοχλιον* is marvelous to behold. It consists of a fenestrated steel casing with joints moved by turnbuckles which apparently fits the patient and holds him rigid. In some of the editions he illustrates apparatus for torticollis, club foot, and various other orthopedic conditions.

In the second part of the work "The Operations of Surgery," Fabricius differs from the majority of the surgeons of his time. So much so, that he was considered ultraconservative. More than that he had carried his anatomy further than the human and invaded the fields of comparative anatomy and embryology. Therefore such a procedure as castration in herniotomy did not appeal to him and the wholesale disregard of hæmorrhage seemed to him unnecessary. Consequently throughout he constantly aims to perfect his surgical technique and stimulates others to do the same.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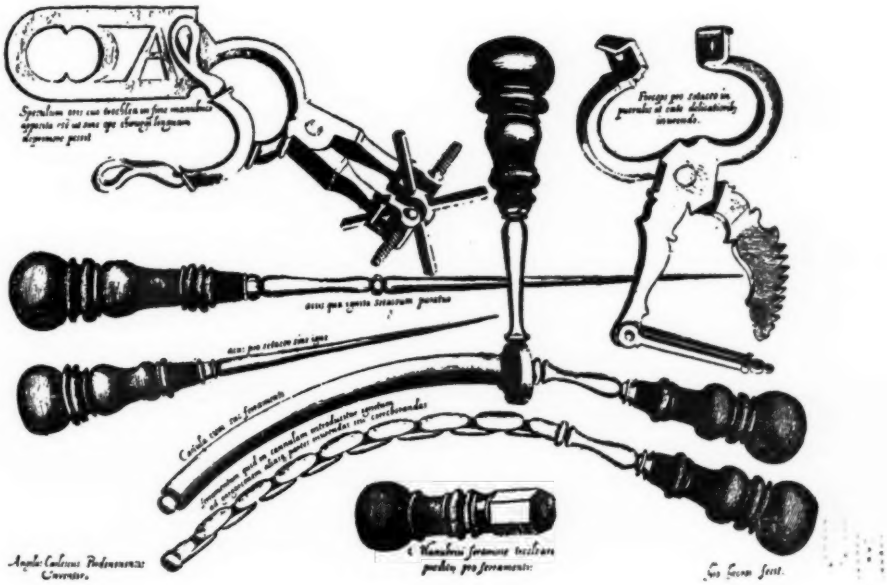
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Forceps pro extrahendis in partubi et inde dilacerandis infantibus.
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Acus pro vulnere cum ope
Cicuta cum ferramento
Ferramentum quod in canalem introducitur ignitum ad corroborandas circa partes vicinales cas corroborandas
Manubrium ferramento trochleam pro ferramento
Angulo Cochleæ Podosteræ Convexior.
Geo Georgi fecit.

REVIEWS OF NEW BOOKS IN GYNECOLOGY AND OBSTETRICS

By GEORGE GELLHORN, M.D., F.A.C.S., Saint Louis, Missouri

THE literary output in gynecology and obstetrics has been exceptionally rich and variegated within the past few months. I am placing at the head of the list of works to be reviewed a new book by Fairbairn[1] because it illustrates, to my mind, in an altogether admirable manner the new phase in the development of gynecology. In 1921, Fairbairn edited, with the help of numerous collaborators, an imposing volume entitled *Gynæcology and Obstetrics*, the great worth of which was recognized in a previous review.[2] He has now gone a step further and written a textbook which he calls *Gynæcology with Obstetrics*. "Gynecology," says the author in a lengthy 'Prologue' which is enlivened by a delicious sense of humor, "cannot be divorced from obstetrics because obstetrics covers the normal and abnormal processes of reproduction and gynecology the diseases and disorders of the reproductive tract. From the point of view of preventive medicine, a knowledge of midwifery is essential to the proper practice of gynecology, and to make it a part of general surgery is to separate the preventive from the curative side. This illogical divorce has been strongly advocated, especially in America, but solely on the narrow ground of technique and without regard to the larger questions of science and education." Gynecology can not be classed as either purely medical or surgical, for it is both. Beyond the problem of the immediate welfare of the individual, gynecology, coupled with obstetrics, is concerned with the study of the whole reproductive cycle—from one generation to the maturity of the next—and by its relations to public health and the social and ethical aspects of the life of the community and the race becomes a fundamental part of the all-embracing scheme of preventive medicine. Fairbairn would have preferred the title Gynecology, had it not been for the traditional usage of this term which restricts it to cover only the *diseases* peculiar to women. It seems to me that the word *Greater Gynecology* would correspond to the term *Frauenkunde* which the Germans have coined to express this newer and wider conception of our special sphere of work.

But, after all, what is in a name? Certain it is that Fairbairn has fully succeeded in his task. The book is divided into eight parts. The first deals, in three chapters, with anatomy and physiology. Then follows the second part of eight chapters on pregnancy, normal and abnormal. The third part treats of physiological and pathological labor in six chapters; the puerperium occupies the fourth, the newborn infant the fifth part. The next part which is quite extensive, is entitled, "The Diseases of the Reproductive Tract." In the chapter on mechanical lesions we find a full discussion of birth traumatisms with cross references to their causation and prevention. In the chapter on infections, the division into local and general infective conditions leads to unnecessary repetitions and detracts somewhat from the clearness and conciseness of the rest of the book. The combination of "overgrowth" and "new growth" seems strange at first, linking together, as it does, two entirely different subjects merely on the basis of external appearance, but on second thought the arrangement makes a strong appeal from the didactic point of view. Throughout this part, the pathological descriptions have been restricted to such points as can be observed by the student during his clinical work or are of moment in practice, because pathology has its own place in the curriculum, its own teachers, and examination. In the two chapters on operative and other therapeutic procedures, obstetrical and gynecological therapeutics are dealt with separately; only the essential points are presented, the details being left "to be acquired in the only way possible, by assisting in the operating theatre or labor ward, or by practicing on the model." The final part consists of two chapters, one on public health service and vital statistics, the other on social and ethical questions such as venereal disease, occupational disability, eugenics, and birth control.

I have felt that only by a somewhat extensive review can one begin to do justice to a book that, with its praiseworthy tendencies, its wide outlook upon the subject, its delightful style, and its frankness, deserves to win for itself a host of friends.

WHAT Fairbairn teaches in a small textbook, Halban and Seitz attempt on an unprecedented scale in their *Biology and Pathology of Woman*.[3] How they have succeeded in their task can be fully appreciated only after the projected eight volumes of the work shall be complete in our hands. In the meantime, I shall merely review several new installments which have appeared since the first three or four sections were reviewed in these pages.[4] These installments are published not in logical order but as the manuscripts of the various contributors are sent in. This accounts for the wide variety of subjects without a close connection, which we find in the installments before us.

Guthmann presents a monographic dissertation of almost 200 pages on physiotherapy. He is guided by the principle that the treatment should not be

[1] Gynæcology with Obstetrics; a Textbook for Students and Practitioners. By John S. Fairbairn, M.A., B.M., B.Ch. (Oxon.), F.R.C.P. (Lond.), F.R.C.S. (Eng.). London: Humphrey Milford, Oxford University Press, 1924.

[2] Surg., Gynec. & Obst., 1922, xxxiv, 694.

[3] Biologie und Pathologie des Weibes. Edited by Hofrat Josef Halban and Ludwig Seitz. Berlin and Vienna: Urban & Schwarzenberg. 1924.

[4] Surg., Gynec. & Obst., 1924, xxxviii, 420.

relegated to attendants. To be successful, this form of treatment requires careful individualization, and only the physician is competent to make judicious decisions. The subject is considered under the headings of mechanotherapy (massage, gymnastics, pessaries, mercury colpeurynter, and—strangely incongruous—resuscitation of the asphyxiated newborn and in narcosis), electrotherapy (diathermy, thermotherapy), and phototherapy. This last section contains, among others, the various ultramodern methods of applying light therapeutically which are, as yet, hardly known in this country. For each physiotherapeutic procedure, the theoretical and biological principles, the technique, indications and contra-indications, and, finally, the results obtained or obtainable are described.

Laqueur contributes a very readable chapter on hydrotherapy in gynecology. In a balneological appendix, the principal watering places in Germany, Austria, and elsewhere on the Continent and the radio-active springs are considered.

An intensely interesting and valuable article on psychotherapy has been written by Walthard, a recognized authority in this field. Psychotherapy represents a new borderland between gynecology and neurology. The subject is not well suited for a brief review, but should be studied thoroughly by every gynecologist. The psychical etiology of many functional disorders of the genital organs and the principles of diagnosis and psychotherapy are presented in clear and concise language. There are, however, limitations to this therapy which must be realized in time, and the gynecologist will have to yield sometimes to the wider experience of the neurologist.

Oertel describes the anatomy, histology, and topography of the female genitals and includes the urinary organs and the intestinal tract as far as they are of practical importance to the gynecologist. Emphasis is laid on gross anatomy; the histology is treated rather briefly. The author denies the existence of the so-called appendiculo-ovarian ligament of Clado. There exists no true "interstitial gland" in the human ovary (as claimed by other contributors in other parts of the work what has been designated as such, is merely the remnant of atretic follicles. Contrary to statements in literature, the sympathetic nerves which supply the ovary do not penetrate beyond the cortex.

The chapter on the comparative anatomy of the female genital tract in domesticated animals, by Schmaltz, is, as far as I know, the first of its kind in a gynecologic work. The far reaching importance to the scientific investigator is self-evident. Many sexual processes in certain domestic animals are very similar to those in the human and can best be studied in the former; dissimilarities, on the other hand, are due for the most part to anatomical differences. After a short general survey, the genital organs, including the mammary gland, are described in detail. The concluding section deals with special features peculiar to each of the following species: horse, cattle, sheep, pig, dog, and cat.

Drahn contributes a chapter on the female genital apparatus in the rabbit, guinea pig, rat, and mouse which will be welcomed heartily by all animal experimenters. The description is based largely on original investigations though the somewhat scattered literature has not been neglected. This paper will save the laboratory worker a great deal of effort and expense.

Eugenics presupposes, among other premises, a knowledge of racial differences of peoples The article before us which is limited to racial differences in women, has been contributed by Stratz. The eminent writer who has published a large number of books on anthropological and ethnographic subjects, has died recently. The reader will find in this, the author's last work, a wealth of interesting and instructive material. Of particular value are his studies on the configuration of the pelvis in lower and higher races. The width, depth, and declination of the pelvis seem to increase in proportion to increasing civilization. In the light of this observation, the small pelvis of the Negress with which we are so familiar in this country, assumes a new anthropological dignity. Of the genital organs, the internal genitals are the only ones which show no racial differences. Ovarian tumors seem to be more frequent than fibroids in the yellow races. The artificial deformity of the Chinese foot is never handed down to the offspring.

The chapter on the physiology of the genital organs has fallen to Fraenkel—a very natural choice since this author has been one of the pathfinders in the physiology of the ovary. It is this particular subject, too, with which he opens his contribution. Then follow the physiology of the tubes, the uterus, the vagina, and the vulva. In all of these chapters thorough histological studies are reported and depicted. Other sub-chapters deal with ovulation and menstruation, the internal secretion of the ovary, the function of the corpus luteum, the innervation of the genital tract, the physiology of the secondary sexual characteristics, the postembryonal development, and the senile involution of the genitals. The exhaustive treatise which is enhanced by several beautiful color plates, is most valuable for the study of the more recent additions to our knowledge of this fundamental subject. The only criticism that one can make, is that Fraenkel—as, indeed, most of the other contributors—pays so little attention to American and other non-German literature.

The endocrine glands form the subject of Aschner's essay. The author who stands in the front rank among endocrinologists, deals, in the physiological part, with the influence of the endocrines on the female genitalia and *vice versa*, under normal conditions. In the pathological part, the relationship between endocrines and the constitution and its anomalies, and the effect of endocrine diseases on genital functions are discussed. There is, in this article, an immense amount of material which testifies to the encyclopædic knowledge and the amazing industry of the author. At the same time, it bears a strongly

individualistic stamp and contains views which are bound to meet with objections. For this very reason, the study of this contribution is intensely stimulating.

The scientific investigator will find much valuable information in Keller's report on the comparative physiology of the sexual organs in domestic and experimental animals. The phenomena of rut and its relation to ovulation furnish the basis for comparisons with the corresponding occurrences in the human female.

Lenz points out, in his essay on race hygiene and heredity, how the gynecologist may contribute to the study of eugenics. The difficult yet exceedingly important subject is presented with praiseworthy simplicity. Mendel's law applies to the human. Sex determination is produced through the male germ and may be influenced at will; whether his purely theoretical suggestions have any practical value, seems rather questionable to me. The predominance of male over female births is explained; likewise the higher fetal mortality of boys. The author presents the mode of hereditary transmission of constitutional anomalies, contracted pelvis, tumors, etc. Operative sterilization and interruption of pregnancy are often desirable for eugenic reasons; "race suicide" need not be feared. Exposure to X-rays is very apt to exert a deleterious effect upon the progeny. Radiologists, as a rule, belong to a class which is of great eugenic value, and should therefore be protected. For this reason, only those who are beyond the reproductive age or otherwise unable to procreate, should be admitted to this occupation. From this brief selection, it is easy to gauge the absorbing interest of the article.

The thesis by Lentz is supplemented, in a way, by a chapter on women in industry and gynecological diseases. Hirsch, the well-known protagonist for "social gynecology," adduces numerous proofs to show the untoward effect of industrial work on the birth rate and on the morbidity and mortality of the working women themselves. The influence of industrial occupation on children, adolescents, and constitutionally inferior individuals, bears an equally close relation to the problem of eugenics. The article, with its numerous tables and curves, is very largely the product of original investigations. Its lessons should become the common property of all gynecologists and the medical profession in general. It may then become possible, perhaps, to remedy some of the evils of modern industrial life in our female population.

A carefully written chapter on hygiene in pregnancy and the non-pregnant state is contributed by Baisch. The principles of hygiene are laid down for all ages of the individual—from birth to senescence—according to the most modern and generally accepted conclusions of our knowledge. It is natural that puberty, pregnancy, and the climacterium should receive the most detailed presentation. Proper nutrition, clothing, exercise, living conditions, and even cosmetics are considered. The grand object or any hygiene of women is this, to prepare the female organism for its great physiologic tasks of pregnancy, labor, and the rearing of children and, after the reproductive age has been reached, to preserve the undisturbed exercise of these functions.

EVERY textbook on gynecology contains at least one chapter on radiotherapy, and there are a number of monographs in various languages which deal with certain circumscribed aspects of the subject. Thus far, however, we have had no textbook in which gynecologic radiotherapy was presented in its entirety. Ernst von Seuffert[1] has now undertaken to fill this gap, and as he is both an expert radiologist and an experienced gynecologist—a very rare combination, indeed.—he appears pre-eminently suited for his task. He addresses himself to three categories of readers: to the practitioner who himself does not apply deep therapy but desires to advise his patients intelligently; to the physician who contemplates using radiotherapy; and to the radiologist to whom the clinical experiences obtained in the large and splendidly equipped clinic of Doederlein in Munich, should be of value.

The work itself is divided into two large sections. The first, of 310 pages, deals with the physics and technique of radiology and comprises an exhaustive discussion of natural radio-active rays (radium, mesothorium) and artificial gamma rays (X-ray apparatus). There is also a description of the various methods and appliances to measure the quantity and quality of rays, and of the fundamental factors in the therapeutic dosage in gynecology. The technique evolved in the principal German clinics is given in full.

The last 230 pages represent the biologicoclinical part. A discussion of the effect of radiation upon the living cell, illustrated with a number of histological pictures, is followed by one on the practical application and the determination of the therapeutic maximum and minimum dose as found by clinical and experimental studies. The concluding chapters are devoted to the uses of radiation in gynecological diseases, both malignant and benign, and its advantages as a pre-operative and postoperative procedure.

It is this clinical section which is of particular interest to the gynecological reader, There is, for example, a curious difference in the reaction of various individuals to X-rays. Women with auburn hair are apt to get erythema from minimal doses. In syphilis, nephritis, and diabetes and in certain rare diseases such as acromegaly, the general radiosensibility is decidedly increased. Certain parts of the body are more easily burned than others. A coexistent exophthalmic goitre may be made worse by radiation of the pelvic organs. On the other hand, desirable by-effects were noted in the immediate and lasting relief of constipation, the shrinking of

[1] LEHRBUCH DER PHYSIKALISCHEN, BIOLOGISCHEN UND KLINISCHEN GRUNDLAGEN DER STRAHLEN- TIEFEN-THERAPIE UND IHRER ANWENDUNG IN DER GYNAEKOLOGIE. By Prof. Dr. Ernst von Seuffert. With a foreword by Geh.-Rat Prof. Dr. A. Doederlein. Berlin: S. Karger, 1923.

vaginal prolapses, etc. Pressure symptoms from large fibroids impacted in the pelvis were relieved almost instantaneously, even before a shrinkage of the tumor could be detected by palpation. Only a very few complications of fibroids (adnexal tumefactions, pedunculated submucous polyps, necrosis or gangrene) call for operation. In all other cases radiotherapy is preferable. An excessively large size need no longer deter us nor the fear of later sarcomatous degeneration which, in itself, is particularly amenable to radiation. Cancer of the cervix is treated exclusively with radium (and mesothorium) in Doederlein's clinic and the prospect of cure is "even now almost twice as good as it was under the best possible circumstances after operation."

This categorical statement makes us suspect that his enthusiasm possibly makes the author too positive in his assertions and, indeed, the clinical part of the book supplies more than one reason for such an assumption. Enucleation of fibroids, for instance, is advised against as probably being useless in relieving sterility or dangerous should conception occur because of possible rupture of the scar. From numerous personal experiences I take exception to this statement and I am certain that many others will agree with me. Again, radiation in small, "stimulating" doses is recommended in the treatment of amenorrhœa, dysmenorrhœa, and sterility—a proposal which impresses me as premature in view of the very meager data at hand.

While, therefore, the book should be read with critical judgment—a postulate which, of course, applies to any scientific work—it may safely be pronounced an intensely interesting, thorough, and decidedly worth while study.

IT is a well known fact that modern X-ray treatment of uterine cancer owes much of its present state of perfection to the joint studies of Wintz and Seitz in the Erlangen clinic. The details of their method are now presented by Wintz in book form[1] and as the work is intended for radiological experts, familiarity with questions of dosage and apparatus is taken for granted. The brief introduction contains practical hints concerning pre-radiation and post-radiation treatment, technical preparation for radiation, auxiliary measures of exposure, copper ionization, etc. The bulk of the book is made up of fifty good reproductions of photographs which clearly demonstrate every step of the Erlangen method and which are accompanied by short explanatory descriptions. The author aims at providing a foundation for the X-ray treatment of typical cases which should be modified to fit the exigencies of the case.

THAT Falta's book[2] is one of the fundamental works on endocrinology and indispensable for any exhaustive study on the subject, has been emphasized in a previous review.[3] In the new edition before us, the title has been changed to "Endocrine Diseases." In other respects, the arrangement of the book remains unaltered. After an introductory general consideration of the ductless glands in health and disease, the diseases of the various glands are discussed in separate chapters, and there are further chapters on conditions which do not fit well into the classification adopted, such as infantilism, chondrodystrophy, obesity, etc. An enormous mass of material has been collected by the author from the literature as well as from personal researches. At the end of each chapter there is an "Addendum" in which the editor has compiled the American and English literature on the topic under discussion. The book is thus brought up to date. Unfortunately, the translation of the German text is altogether too literal both as to single expressions and the construction of sentences. This renders the reading unnecessarily difficult, frequently obscures the meaning, and in general detracts from the appeal and the usefulness of the work.

IN making each individual endocrine gland a subject of information, which is the usual mode of presentation in textbooks on endocrinology, it is rather difficult to give to the student a unified picture that will clearly show the meaning of the internal secretions in the life cycle. For this reason, Weil approaches his subject in a different manner.[4] He deals with the internal secretions—he proposes for these the term "incretions"—as agents concerned in the production and regulation of the separate bodily functions and describes the part which the various incretions take in each particular life process. This, then, is primarily a physiology of the internal secretions though the application to pathological alterations is either self-evident or expressly pointed out by the author, and a glance at the Table of Contents will make his plan still clearer. We find there a chapter on the physiology of the blood, others on the circulation of the blood, respiration and voice production, metabolism, growth and bodily form, the mind and the internal secretions, methods of testing for internal secretions, etc. The author evidences everywhere the complete mastery of his subject, the intimate knowledge of the literature of the world, and the critical judgment that are demanded to give to the reader a firm foundation for further study. The book should, therefore, be most welcome to students and practitioners and this appraisal seems fully confirmed by the fact that in little more than two years three German editions have become necessary. Its value to the specialist is inferred from some of the chapter headings mentioned. The gynecologist will find all the known facts about the rôle of the endocrines in his particular field in the chapters on reproduction and the

[1] DIE ROENTGENBEHANDLUNG DES UTERUSKARZINOMS. By Prof. Hermann Wintz, M.D., Ph.D. Leipzig: Georg Thieme. 1924.

[2] ENDOCRINE DISEASES INCLUDING THEIR DIAGNOSIS AND TREATMENT. By Wilhelm Falta, Vienna. Translated and edited by Milton K. Meyers, M.D. 3d ed. Philadelphia: P. Blakiston's Son & Company, 1923.

[3] SURG., GYNEC. & OBST., 1916, xxiii, 368.

[4] THE INTERNAL SECRETIONS. By Dr. Arthur Weil. Authorized translation from the 3d German ed. by Jacob Gutman, M.D., Phar.D., F.A.C.P. New York: The Macmillan Company, 1924.

sexual impulse; but the other chapters, too—notably those on metabolism and bodily growth, the latter with its sub-headings on pelvic girth, secondary sex differences, transformation of sex, and hermaphroditism—will offer him many a valuable suggestion. It is a fascinating book which can not be recommended too highly. Previous translations into Russian, Spanish, and Japanese have now been followed by an English translation which is so purely idiomatic that its character of a translation becomes apparent only upon the title page. The translator has rendered a distinct service to the English reading public and he has added an æsthetic enjoyment to the mental stimulation of the original.

TIMME presents in unchanged form his Lectures on endocrinology[1] which appeared in the *Neurological Bulletin* in 1921. The author deals with each of the endocrine glands separately in the accepted order; but he injects a new point of view into the discussion by describing the activities of the endocrines in relation to the three spans of the human life cycle: one from birth to puberty, the next from puberty to the prime, and the last through a gradual deterioration to dissolution. He also takes pains to point out again and again the intimate interrelationship of all endocrine glands which comes into play in many morbid states and makes it extremely difficult and often impossible to determine the original gland at fault. It is unavoidable that in a subject concerning which knowledge is being as rapidly accumulated as in endocrinology, these lectures do not embody the information acquired in the last three years. But as Timme is a master of literary style, his little book makes reading most enjoyable and profitable and deserves a wide circle of readers.

PRURITUS is so distressing a symptom and very often so refractory to treatment that any new information regarding its relief can only be welcomed. The subject, however, is so circumscribed that it may suffice for a magazine article or a chapter in a textbook but should not fill an entire book. This difficulty is encountered by Montague,[2] and in order to cover 186 pages the author has been led to frequent repetitions, to the detailed introduction of irrelevant matter, and to branching out into discussions which are not germane to the subject. When all superfluous and extraneous matter is excluded, there remain a number of excellent photomicrographs and other pictures and a good consideration of pruritus from the standpoint of the proctologist. To the gynecologist the book will prove inadequate. Not only are some of the most important general causes, such as diabetes, not stressed sufficiently, but the enumeration of specifically gynecological causes is incomplete. There is, for instance, no mention made of kraurosis and leucoplakia of the vulva or of lack of cleanliness, smegma, pediculi pubis, etc. In the historical introduction no word is said about the fundamental histologic studies by J. Clarence Webster in 1891, and Kelly's classical description in his Medical Gynecology is ignored. Among the gynecological causes cited by the author, there are several which can not be accepted without objection. For example, cystic ovaries and chronic salpingitis are not apt to cause pruritus. The author believes that, when senile changes occur in the uterus in menopause, "the utricular glands become hyperactive, and fluid is retained in the uterine cavity." That this is a misconception, need not be pointed out to gynecological readers. The author probably had in mind the picture of "senile vaginitis," a very common cause of pruritus, which, however, is due to desquamation of the upper layers of the vaginal mucosa and insufficient regeneration of the basal layer.

The book ends with a recommendation of operative treatment for which the author has designed an original method.

TWO textbooks on obstetrics for nurses have appeared in new editions. Both Reed[3] and Bacon[4] present the matter in very clear and concise language and simplify the issue still further by avoiding all controversial questions and introducing only a minimum of theoretical considerations. It has been argued against nurses' textbooks written by physicians that they teach "too much" and it must be admitted that, on the whole, there is but little difference between the books before us and any students' textbooks of small size. In fact, Bacon maintains that the rank and file of the profession really need not know more than he offers, and so he designates his book "A Manual for Nurses and Students and Practitioners of Medicine." While, thus, there seems to be some ground for an adverse criticism, it must be remembered that in obstetrics, almost more than in any other branch of practical medicine, there is an exceptionally wide field for the initiative of the nurse. It is she who has to watch the patient for hours before the doctor arrives, and in sudden complications (bleeding, convulsions, etc.) she may have to administer first aid unless the patient is in a hospital and under observation by the house staff. She, therefore, *must* know more than the mere routine of nursing and for this reason, books like those before us, answer a distinct want. From actual observations in daily practice, however, we need not fear, despite these and similar books, that the nurse will learn "too much."

FROM Talleyrand's famous dictum "La statistique, c'est un mensonge en chiffres" to the more recent assertion that "by statistics you can prove anything—even the truth," there is hardly

[1] LECTURES ON ENDOCRINOLOGY. By Walter Timme, M.D. New York: Paul B. Hoeber, 1924.

[2] PRURITUS OF THE PERINEUM (PRURITUS ANI, VULVÆ AND SCROTI). By Joseph Franklin Montague, M.D. With a foreword by George David Stewart, M.D. New York: Paul B. Hoeber, 1924.

[3] OBSTETRICS FOR NURSES. By Charles B. Reed, M.D. 2d ed. St. Louis: C. V. Mosby Company, 1923.

[4] OBSTETRICAL NURSING; a Manual for Nurses and Students and Practitioners of Medicine. By Charles Sumner Bacon, Ph.B., M.D. 2d ed., revised. Philadelphia and New York: Lea & Febiger, 1924.

a single epithet of an opprobrious nature that has not been applied to statistics at one time or another. Yet, by statistics we live, and by statistics we die if the life insurance statistics by which our premiums are determined, have any significance; and in medicine, in particular, we swear by statistics even though we may grumble at times that they are not worth a tinker's dam. Pearl[1] believes that the time has come to introduce exact scientific methods into the collection and tabulation of medical thought and action. "This book," says the author, "is written for the medical reader primarily. The illustrations of method are mainly chosen from that fields. Biometric methods already have a secure place in general biology. Their use is devoloping in the medical field with extraordinary rapidity just now. It has seemed to me on this account that an elementary introduction to the subject designed primarily and directly for medical readers might be found particularly useful at this time." To the average clinician who, like myself, has heretofore used and computed figures rather lightheartedly, the book opens a vista into an unknown territory. The historical prologue is immensely interesting, but the reading soon becomes more difficult. At times it is as thrilling as a page of logarithms, and forgotten memories of school mathematics have to be revived to follow the author on his way through rates and ratios, life tables, the measurement of variation and of correlation, etc., and to understand the importance of avoiding the "probable error." Pearl is professor of biometry and vital statistics in Johns Hopkins University, and his work will in time bear fruit in the greater reliability of medical statistics.

[1] INTRODUCTION TO MEDICAL BIOMETRY AND STATISTICS. By Raymond Pearl. Philadelphia and London: W. B. Saunders Company, 1923.